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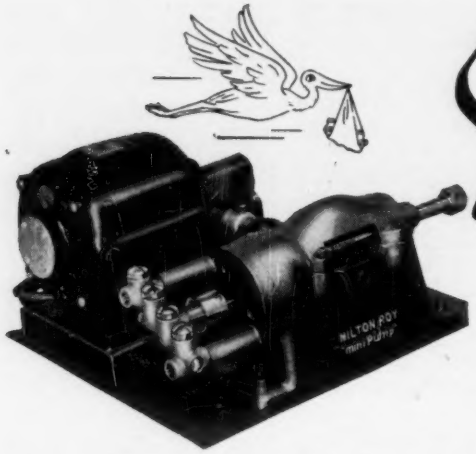

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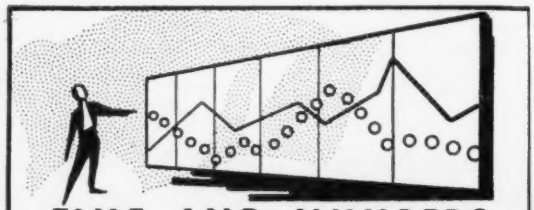

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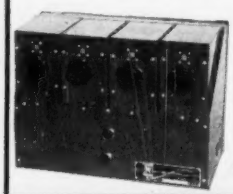

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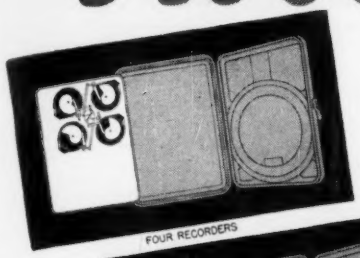

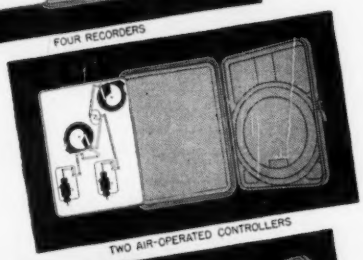

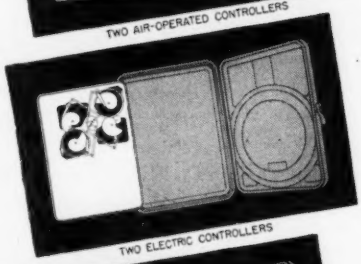

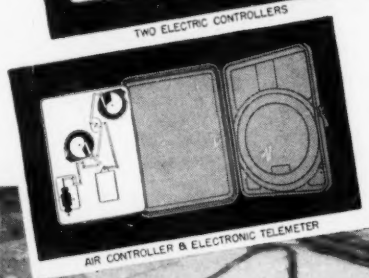

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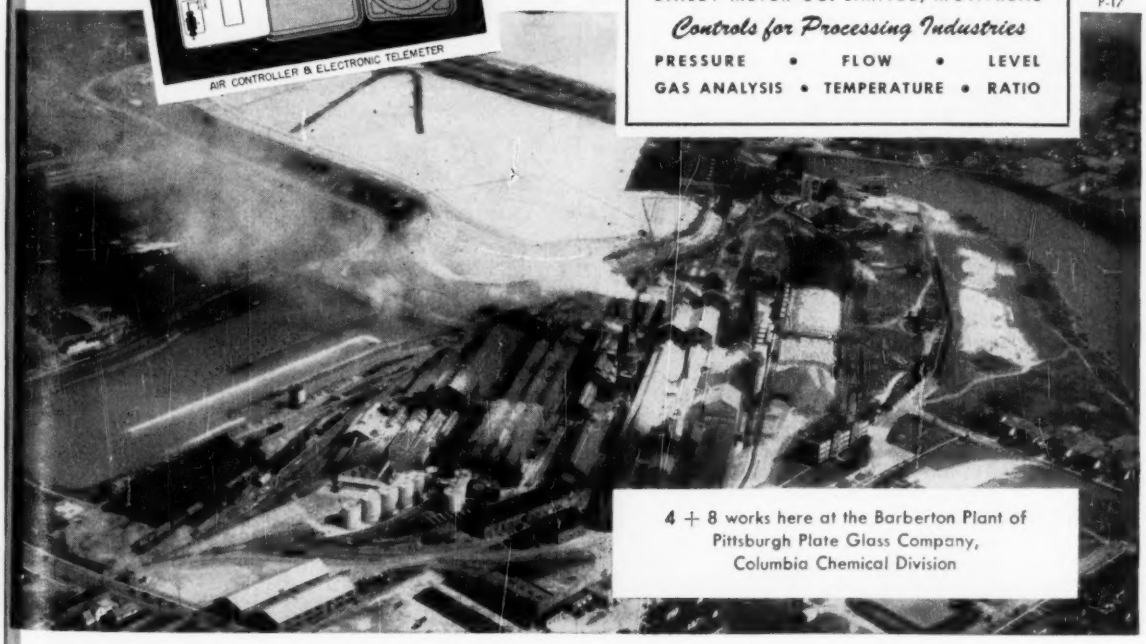

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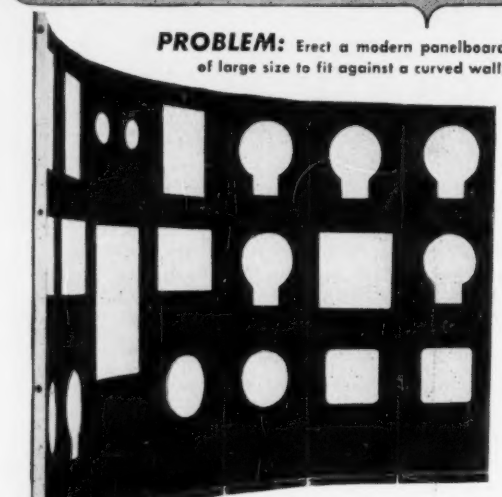

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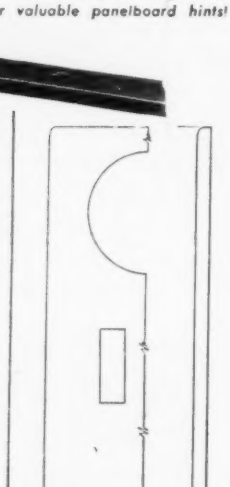

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Instruments

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Owing to the importance of temperature measurement and control in all industries, we gladly "yield the floor" this month to the Proficient Priests of Precision at the NBS.

National Bureau of Standards
U. S. Department of Commerce
Washington 25, D. C.

Technical Report 1414

REVISION OF THERMOCOUPLE TABLES

An extensive project is now under way at the National Bureau of Standards for revision of all the common thermocouple tables in order to take into account the recent changes in electrical units and in the International Temperature Scale. Present plans call for the publication during 1950 of eight tables giving the temperature-emf relations for platinum-platinum rhodium, chromel-alumel, and copper-constantan thermocouples.

The temperature-emf tables for thermocouples previously issued by the Bureau have been widely used in science and industry, not only to convert thermocouple voltages into the equivalent measured temperatures but also in the preparation of purchase specifications for thermocouple wire and in defining the relation between impressed emf and scale reading for pyrometers which indicate temperature directly. Recently, however, in accordance with international agreement, the Bureau adopted the absolute electrical units and began using the definitions of the new International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other laboratories and industries. Revision of the thermocouple tables was then advisable in order to make them consistent with former usage.

In the preparation of the tables, emphasis is being placed on convenience for use. Thus, the explanatory text will be short, the numerals will be as large as practical, and the layout of pages and headings will be arranged to facilitate interpolation. The argument will be presented at one-tenth the interval given in the original tables. Inverse tables, formerly lacking, will also be included. Each table, together with its inverse, will be issued as an NBS Miscellaneous Publication and, when announced, will be available from the Superintendent of Documents, U. S. Government Printing Office. The following tables are expected to become available during 1950:

1. Reference table for platinum vs platinum-10% rhodium thermocouples: emf at intervals of 10 microvolts vs degrees C; temperature at intervals of one degree C vs microvolts.

2. Reference table for platinum vs platinum-10% rhodium thermocouples; emf at intervals of 10 microvolts vs degrees F; temperature at intervals of one degree F vs microvolts.

3. Reference table for platinum vs platinum-13% rhodium thermocouples; emf at intervals of 10 microvolts vs degrees C; temperature at intervals of one degree C vs microvolts.

4. Reference table for platinum vs platinum-13% rhodium thermocouples; emf at intervals of 10 microvolts vs degrees F; temperature at intervals of one degree F vs microvolts.

5. Reference table for chromel-alumel thermocouples; emf at intervals of 0.1 millivolt vs degrees C; temperature at intervals of one degree C vs millivolts.

6. Reference table for chromel-alumel thermocouples; emf at intervals of 0.1 millivolt vs degrees F; temperature at intervals of one degree F vs millivolts.

7. Reference table for copper-constantan thermocouples; emf at intervals of 0.1 millivolt vs degrees C; temperature at intervals of one degree C vs millivolts.

8. Reference table for copper-constantan thermocouples; emf at intervals of 0.1 millivolt vs degrees F; temperature at intervals of one degree F vs millivolts.

The NBS tables for iron-constantan thermocouples will not be revised until completion of an investigation into the properties of some commercially available iron-constantan thermocouples, which is now being carried out by the Bureau in cooperation with the Scientific Apparatus Makers of America.

A limited number of rough-draft advance copies of the first two publications has been prepared to meet interim demand where the need is great. Others will become available in the order listed. Inquiries and suggestions regarding the tables should be addressed to Dr. Robert J. Corruccini, Pyrometry Laboratory, National Bureau of Standards, Washington 25, D. C.

Economics *of* Instrumentation

By G. W. McCULLOUGH, Vice President and General Manager, Phillips Chemical Company, Bartlesville, Oklahoma

Introduction

FOR many years the factors required to obtain the best in performance at minimum cost from an automatic plant process control system have been of the deepest interest to the Management of the Phillips Petroleum Company. This interest in plant control was born during the earliest days of the Petroleum and Gas Industry, when the first natural gasoline plants of simple design, operating to produce a fuel of limited specification, utilized automatic controls as the most economical means to achieve the maximum production.

As the industry continued to develop, and new uses were found for the varied components of natural gas and gasoline, the instruments used for the automatic control of process flows were progressively improved. With the advent of the Chemical Plants employing petroleum products and feed stocks, the proper economical use of instruments to obtain quality specification product through continuous flow demanded the immediate development of many types of new instruments.

Instruments are now in use that handle precise and complicated cycling schedules that are too rapid, delicate or complex to be entrusted to human hands, thus making possible mass production of high-purity products that were only laboratory dreams a few years ago. With proper controls, duplication of any operation is possible, and the exacting standards of specifications of a product can be constantly maintained.

Too, World War II originated many new types of instruments and this war was won by the United States and its allies in large part because this nation was able to out-do its enemies in producing the technical instruments needed, and in training personnel in great numbers to operate them. The production of the atomic bomb was made possible because the talents of all industries were pooled, and the wonders performed at Oak Ridge and its sister plants enabled the quicker subjugation of Japan through the reduction of Hiroshima and Nagasaki. All America can be thankful for the savings in lives and money thus obtained.

These complex instruments have not been used to any great degree in present-day plant operation, but the plants of the future built as complete new units will call for the adaptation of some of these items.

From the standpoint of production, efficiency and investment, the writer has carefully surveyed the subject of plant instrumentation based upon the operation of several types of plants. For the consideration of members of the industry, many of the points studied during these surveys, applicable to general use, are presented herewith.

Factors Affecting Cost

In an approach to an analysis of the requirements for good measurement and control, several items must be considered to assure that the plant process flows will be properly provided with instrumentation consistent with the general purpose of the plant. Competition in the petroleum and chemical fields is becoming keener each year, and the future will see succeed those companies which recognize and make use of the advanced instruments available to the industry.

Some of these factors are routine and, while involving matters of the greatest importance in the operation of the measurement and control equipment, are of basic knowledge of a group such as is present here today. It has been decided to discuss these interesting factors but briefly in order to favor a discussion of the instruments which will be possible for the operation of the plants which will be developed in the future.

Basic Instruments. In broad terms, these instruments may be classified as those used to effect quality control differing, in the main, from the routine type used for temperature, pressure, level and flow control in that they are located in the process closer to the product stream, and function to reset the routine type instrument for a finer cut. This close control is not necessary in the standard gasoline plant, since its product is usually delivered to a central point for fractionation and purification. However, in a special product plant manufacturing individual hydrocarbon cuts, and in special product plants, i.e., producing butadiene to a high standard of purity, extremely close control is necessary to assure that the product meets specification. This is true also with regard to chemical product plants manufacturing ammonia, ammonium sulphate, ammonium nitrate, nitric acid, etc.

Safe Practice. The use of the more complicated instruments sometimes requires that an interlocking sequence of operation be used so that flows cannot be mixed accidentally with an explosive hazard created. This concern for safe practice has, of course, added to the cost of instrumentation of petroleum-chemical product plants.

Cost Center Records. Another item that must be considered as a factor affecting the instrument percentage cost figure is the provision for proper records showing cost and production figures. In most petroleum-chemical plants the cost control must be carefully watched, since most process streams involve costly ingredients.

Project Permanency. Too often in the past, plants have been built on the assumption that they would be short-lived; however, as the continued use developed, revamping and adding instrumentation has increased the cost percentage above that necessary had it been possible to base the cost on the actual period of operation.

Cascade Type Controls. The use of cascade type control installations, whereby an over-riding controller is used to reset an instrument to position a motor valve controlling a process variable, eliminates unusual or lengthy process time lags. Instruments used in this manner provide a means of obtaining precision quality and are adaptable to use with computer type panels when such are more fully developed.

Typical Process Use

Gasoline Plant. The instrumentation required for a natural gasoline plant is even today of a simple nature. The principal changes have been in the use of improved types of instruments for standard variable control. Transmission of flow differential, pressure and temperature has permitted the centralized location of equipment and has eliminated much of the difficulties encountered in winter operation.

Reducing the number of service calls and process interruptions has saved thousands of dollars. Too, the use of this type instrumentation has afforded a stepping stone useful in the transition steps necessary to the training of personnel capable of handling the more complex instruments required in other type plants.

Table 1 includes figure for an early-day type plant using the simpler type of direct-connected instrument. The cost percentage figure is low, since the type of instrument was based on that needed for the manufacture of a product to less stringent specifications than those demanded of today's natural gasoline plant.

Table 2 shows the investment necessary to a modern natural gasoline plant. Using a leaner natural gas as feed presents more difficult extraction problems and, operating to maximum efficiency on a year round basis calls for winter-proof construction. The dollar value of the product is not too different from that of the early gasoline plant but the operating conditions have changed, requiring better instrumentation to make possible the economical processing of the lean gases.

Fractionation of Hydrocarbon Feeds. In the fractiona-

*Presented at Short Course on "Instrumentation for the Process Industries," Texas A & M College, Oct. 12-14 1949.

	Table 1 Early Day Gaso. Plant	Table 2 Modern Gaso. Plant	Table 3 Refining Crude Unit	Table 4 Spec. Product Butadiene
Total Plant Investment	$1,600,000	$2,500,000	$2,250,000	$38,000,000
Instruments Installed	$ 25,000	$ 90,000	$ 125,000	$ 2,200,000
Percentage	1.5 percent	3.6 percent	5.5 percent	5.8 percent
Selling Price	5 cents/gal.	5 cents/gal.	7 cents/gal.	12 cents/pound
	Table 5 Chemical Plant Anhydrous Ammonia	Table 6 Chemical Plant Nitric Acid	Table 7 Chemical Plant Ammonium Nitrate	Table 8 Chemical Plant Ammonia Sulphate
Total Plant Investment	$23,000,000	$1,500,000	$3,000,000	$1,800,000
Instruments Installed	$ 690,000	$ 30,000	$ 60,000	$ 40,000
Percentage	3 percent	2 percent	2 percent	2.2 percent
Selling Price	3.75 cents/pound	5.5 cents/pound	3 cents/pound	2.52 cents/pound

tion of hydrocarbons to a desired kettle and overhead product, the vapor pressure at any given tray location within the vessel is an indication of the purity of the product at that point. A recent development has brought forth a differential pressure controller utilizing a bulb filled with the product desired at that point. Installed in the vapor space above the tray in which a quality product is desired, this controller functions so that, as the pressure at that point of application varies, the product in the vessel operates one side of a flexible diaphragm opposed by the vapor pressure within the sealed tube of the instrument representing the product desired. The movement of the diaphragm causes an actuating air pressure to vary the ratio of reflux to column feed to maintain proper quality overhead and kettle product accomplished as resetting a flow controller on the reflux line.

Table 3 shows the instrumentation cost for a refining plant. Many of the comments for the modern gasoline plant apply to the refinery except that a higher priced product permits more complete instrumentation based upon more precise quality products and year round operation.

Butadiene and Butane. Data from government-owned and-built plants have been reviewed and the use of the spectrophotometer using infrared ray phenomena to analyze the constituents of a flow stream has been developed to the extent that it is now suitable for control applications. This type instrument has been used for several years as an indicating or recording analyzer but only recently has its control possibilities been utilized. The greatest handicap to the earlier use of this instrument was the necessity to take time to develop personnel capable of handling the equipment. Also, some of the mechanical difficulties involved, such as those encountered obtaining a clean flow stream, clean sample piping, etc., had to be overcome. This instrument, used to determine the purity of a butadiene flow stream, has greatly increased the efficiency of production. This has been possible through the anticipatory information obtained quickly so that necessary process variables could be changed before the column was upset beyond quick adjustment.

The spectrophotometer has possibilities also in the analysis of a flow stream containing butane used as feed to a butadiene manufacturing plant. The quality of the butane stream is maintained through the proper adjustment of process variables. The use of this type instrument will be greatly expanded in the next few years.

Since the production of butadiene in the plant built and operated by Phillips Petroleum Company for the United States Government was based upon the two-step catalytic dehydrogenation of butane, cyclic operation of the process control gate valves was necessary. Owing to the multiplicity of valves and the short time periods involved, human manipulation of this equipment could not be relied upon for the repeated operation of these units to a predetermined cycle.

The timing program was further complicated since purging of the flow lines was required before the hydrocarbon stream could be readmitted to the lines used jointly for regeneration and feed. An electrically-wired interlocking system was employed to assure one correct valve sequence to avoid an explosion hazard which would be presented should hydrocarbon and the oxygen containing regeneration gas streams be mixed.

An electric timer was used to send an electrical impulse to the control valve with the cycle temperature program developed by means of a metal circular chart cut to a desired contour. These two instruments were synchronized electrically so that the proper valves were opened or closed during optimum temperature conditions.

The instrumentation necessary to the two catalytic dehydrogenation steps effected quality control, simplifying the fractionation steps following each catalytic unit. Selective absorption and purification with furfural as the medium was employed to separate the butenes for feed to the second catalytic step and to secure butadiene as the final product after the second dehydrogenation cycle. Close control of the process variable was needed in these units to avoid unnecessary loss of absorbent and to avoid the production of butadiene which would not meet the exceptionally high standard of purity demanded for use as feed to the copolymer plant producing latex used in the production of synthetic rubber.

Table 4 shows the cost comparison for a special product plant. Here it will be seen that the price of the product has greatly increased. The problems of precise control and year round operation permit that the complex instrumentation necessary to achieve quality control may be a relatively high percentage figure.

Nitrogenous Products Plants

Anhydrous Ammonia. The manufacture of anhydrous ammonia has presented an opportunity for the use of many types of quality control instruments with much yet to be gained as further knowledge is obtained. Phillips Chemical Company's entry into the production of ammonia has increased the use of automatic control to most of the process flow. The original plant design, erected during the war period 1942-3, was based on World War I chemical plant practices with many flow streams operated manually. It has been necessary to educate the present operators in the use of this new type equipment and to allay their fears regarding the reliability of its operation. To accomplish this necessitated the strengthening of the instrument section personnel and providing facilities for 24-hour service.

New instrument and control applications which have been completed and are under study are numerous. In the synthesis step, liquid level control of the product from the cold exchangers has been possible through the development of a displacement type level controller suitable for the high pressure necessary to the application. The use of instruments at this point has released personnel to supervise other critical operations within the unit and has provided a more constant flow through the plant.

Another quality control instrument is a methane analyzer considered for use on the nitrogen-hydrogen stream from the converter. Study of this application has not been completed and is mentioned at this time only to indicate a possible location or further automatic control of a plant process step.

In the gas reforming step, consideration has been given

to using a hydrogen analyzer as a quality controller. As in the above-mentioned application, study is not complete at the moment as to the exact mechanical adaptations necessary; however, it too, is mentioned to afford an insight into the wealth of applications yet to be explored where automatic control of process variables can be made economically to provide more precise quality product.

Table 5 contains the most comparison for a plant producing anhydrous ammonia. In this type plant the percentage cost figure is somewhat low because of the use of alloys for many of the lines and the extreme operating pressures needed in the synthesis step of the process.

Nitric Acid. In the manufacture of nitric acid, the oxidation of ammonia in the presence of suitable catalyst at elevated temperatures is accomplished with the catalyst gauze temperature controlled by permitting the by-pass of a volume of cool air. However, in this process the presence of oxygen in the effluent gas stream from the nitric acid absorber is a critical indication of the efficiency of the total process, and is used to reset the temperature control instrument maintaining temperature preceding the catalyst chamber. In this manner process lag through the entire system is cut to a minimum with the quality of the feed to the absorption column maintained to a precise quality.

In this same process another application for quality control is the use of a conductivity control unit calibrated in terms of percentage concentration nitric acid. This unit is connected to the outlet of the absorption column with its control established through a motor valve located on the water to the tower. This application is a direct control unit aimed to maintain a specific quality product.

Table 6 shows the cost figures for a plant manufacturing nitric acid using ammonia and oxygen reacting in the presence of a catalyst. The total investment of such a plant is not great, but the cost percentage figure is low because of the use of special alloys in the vessels and lines, making the investment out of the usual proportion for controlled variables to major equipment.

Ammonium Nitrate. In the manufacture of ammonium nitrate, the mixing of ammonia and nitric acid to the proper proportion is the key operation of the process, and the pH indication of the condensate from the neutralizer is a critical criterion of the efficiency of proper mixture. Ratio flow controllers are used on the ammonia and acid streams preset to a definite ratio and account for major control of the two flows. The pH value determined from a sample stream located in the vapor or condensate stream from the neutralizer is used by means of a pH controller to reset the ratio controller. This allows the pH value to be adjusted to that desired for a more perfect ratio and avoids much of the time lag which would otherwise be introduced into the system.

Table 7 shows a typical chemical plant manufacturing ammonium nitrate. This plant shows the cost percentage figure for instrumentation rather low. This is because the major equipment, although based upon much smaller process flows, requires many of the vessels and other equipment to be of special alloys which greatly increase the cost of total investment to that for measurement and control.

This table gives relative figures for a chemical plant manufacturing ammonia. In this plant Phillips has made changes from many chemical industry methods of operation to those based upon petroleum industry practices. While quality control application equipment is used, this plant represents compromise instrumentation.

Ammonium Sulphate. A plant in which sulphuric acid and gaseous ammonia are combined to produce ammonium sulphate was recently completed. This plant based upon continuous process flow operation has provided applications for automatic control not encountered in some of the earlier plants producing ammonium sulphate.

A pH recorder is used to afford a means of checking the efficiency of the chemical reaction of the sulphuric acid and ammoina gas and as a guide to the control of the product to the desired quality.

A ratio controller is used to provide the correct amount of acid dependent on the base flow of ammonia gas. Through this means small fluctuations in ammonia gas flows are adjusted automatically by the increase or reduction in the amount of acid admitted to the ammonia stream. This instrument installation has reduced the effect of the human element present when these two flows are manually set to a fixed ratio.

Temperature controllers make continuous flow through automatic dryers possible, eliminating the batch plant type of operation which was often used in the past. Automatic weighing and bagging machines further facilitate the handling of the product to storage.

Table 8 presents cost figures for comparison with other chemical product plants.

Computers Used with Quality Controllers. All of the control applications and the instruments used to achieve an end product are those used to maintain quality and are of the type which will be suitable for adaptation to a computer type panel.

Using a computer in conjunction with suitable instruments, it will be possible to turn a dial to a quality desired, and the computer will then function to reset a ratio control of feed to reflux for a column, or control the water flow over a tower to maintain a proper concentration of an acid, etc. Though at the present moment these computer instruments are used in many phases of aircraft navigation, the instrument companies have fabricated experimental models using principles as indicated herein for process control and it is possible that units will be available to the industry for special application in the near future.

A plant built to operate using some modification of the Fischer-Tropsch process to manufacture gasoline using methane as the primary hydrocarbon, will require a cost percentage figure in the neighborhood of ten percent. This will be due to the exacting nature of the process not only for the production of the oxygen, but in the reforming and synthesis steps as well.

Perhaps better instrumentation will help to make this process financially attractive and in some part permit its economical construction.

Future and Personnel

A main factor upon which the use of the more complex instrumentation is based involves the training and developing of personnel qualified to design, operate and maintain this complex instrumentation. In the early days of the petroleum industry the instrument men were chosen from personnel who had shown an ability to repair things, hay binders or automobiles. Today's specialized equipment is a challenge to the technical graduation.

The colleges of Engineering at several schools have now included in their curricula, courses on instrumentation which provide a means of training men during their school years. This inclines these men further toward an interest in this work and, from this group, management can select men who have at least indicated a desire to follow this phase of engineering.

Through this step educational groups have acknowledged the need for basic training in instrument design and application, and are attempting to do their part in the advancement of measurement and control.

Too, the recent establishment of the Instrument Society of America, organized to function along the lines of other bodies such as the American Society of Petroleum Geologists, American Society of Mechanical Engineers, etc., has done much to alert men responsible for the economical production of special products to an understanding of the important place automatic control instruments occupy in present-day plant operation.

In order for a technical graduate to be interested in following this phase of engineering has meant that the management of the various companies in the Petroleum-Chemical Industries has had to become measurement and control conscious. Management has had to base its concept of personnel placement in an organization chart in a strong enough position, so that a technical graduate could be satisfied with the opportunities for salary and progress, using measurement and control as his medium. Many of the larger companies, recognizing that it will be through the further use of the technical graduate that added advantages from better instrumentation will be gained, have placed graduates in the company engineering and operating departments to serve as key personnel.

Purdue's Course *in* Engineering Instrumentation

In the School *of* Chemical *and* Metallurgical Engineering

By GEORGE W. SHERMAN, Associate Professor of Chemical Engineering,
Purdue University, Lafayette, Indiana.

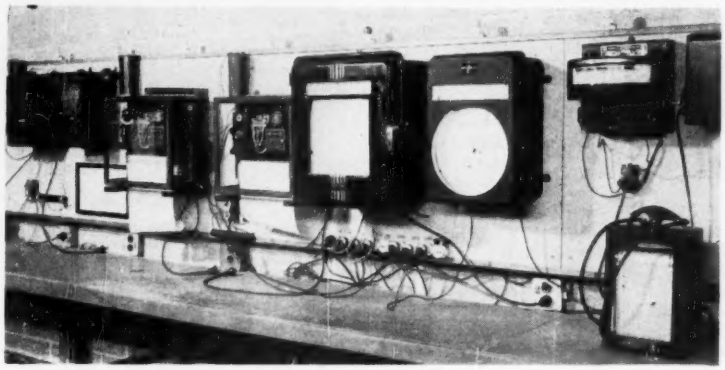
IN response to the rapid increase in instrumentation in all types of processing, many schools have included this subject in their engineering curricula.

There is an urgent demand by industry that the engineering student have training in the instrumentation field. Therefore, it seems that more attention should be given to this often-neglected field.

Some have separate courses while others have the instruction included in other courses. At Purdue University we have a separate course administered in the School of Chemical Engineering.

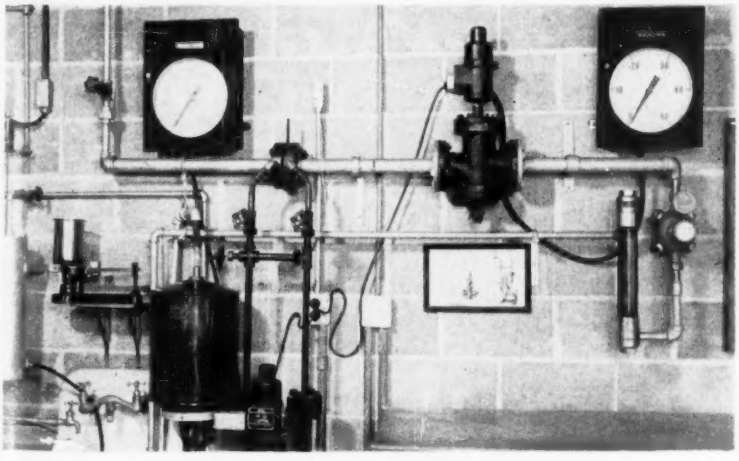
A separate course seemed more desirable for two reasons. First, when administered as a separate course the student has his attention focused on the material in a much more forceful manner than if it is attached bit by bit to other courses where he may be led to think of it only as a "filler." Secondly, it is much more desirable to have one member of the teaching staff, who is trained in this particular field, administer the course — because he can give much of his time and energy to the subject rather than to attempt to have the entire staff teach the subject as a side line. The latter method might be, in many cases, more of an annoyance than a matter of interest to the staff member, who has his main interest in another subject.

The subject matter of instrumentation is closely related to many other courses and, when administered late in the curriculum, serves as a means of review and as a correlating course. Such a course, properly taught, will help the students to comprehend the fact that each integral part of the plant is an important link in an over-all project, the aim of which is to produce some product in the most economical way possible. Such a course cannot help but enlarge the student's view of process operation.



Recorders and Controllers.

The course in Engineering Instrumentation at Purdue University was started in the fall of 1913 under the name of "Pyrometry" at the request of Professor H. C. Peffer who was at that time the Head of the School of Chemical Engineering. The course at that time was confined to the measurement and control of temperature. Later, as automatic control methods were developed for other conditions and properties, the course was expanded to include flow, flow ratio, pressure, level, viscosity, pH, smoke density, humidity, specific gravity, and CO_2 measurement and control. About 1935, observing that M. F. Behar had been using his term "Instrumentation" in his serials, we called it by that name.



Liquid Flow Meters.

At the beginning of the course the student is made acquainted with the basic principles of measurement. This part of the course includes a discussion of accuracy and sensitivity and their effect on the end product of the control. Errors due to the measuring instruments are considered fully, including the changes in the condition being measured due to the measuring element, and those errors due to the various lags, etc.

In the measurement and control of temperature the student studies thermoelectric, resistance, pressure, radiation, optical, and photoelectric methods. This work includes the consideration of various measuring elements as best applied to the measurement of temperature under various conditions. Studies of the measuring instruments such as the millivoltmeter and potentiometer, together with the advantages and disadvantages of the various types, are included.

Consideration is given to the problem of thermometer wells and protecting tubes, including lag problems, corrosion etc.

In the measurement and control of flow and flow ratio, the Venturi, the orifice plate, and Pitot tube, the rotameter, current type meters and volumetric meters are discussed.

For the other conditions and properties, such as level, pressure, humidity, viscosity, smoke density, and pH, there is a similar coverage.

In the problems of control, various types are studied, starting with simple on-off types and progressing through proportioning, proportioning with reset, and on to the more recent types. The operating characteristics and proper application of the various types are discussed.

In the study of control problems, comparison is made between self-operated and servo-operated devices. Telemetering and signal transmission is fully

covered as is the relative advantages of electric, pneumatic, and hydraulic systems for relay and positioning devices.

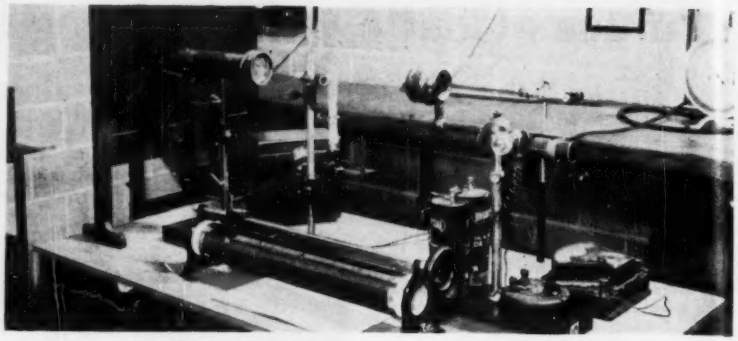
EXPERIMENTS FOR LABORATORY

George W. Sherman

1. Study of resistance thermometer.
2. Freezing point method of thermocouple calibration.
3. Calibration of thermocouples by comparison.
4. Installation of thermoelectric pyrometers.
5. Study of lags in measurement.
6. Study of automatic control mechanisms, on-off.
7. Study of electric proportioning controls, reset, rate.
8. Study of pneumatic proportioning controls, reset, rate.
9. Study of radiation pyrometers.
10. Study of optical pyrometers.
11. Measurement of emissivity.
12. Flame temperature measurement, line reversal.
13. Study of gas flow meters.
14. Study of liquid flow meters.
15. Level and density measurements and control.

ITEMS TREATED IN LECTURES FIRST MONTH

1. Direct and Inferential method of measurement
2. Accuracy
3. Sensitivity
4. Instrument Change
5. Seebeck Effect
6. Peltier Effect
7. Thompson Effect
8. Qualities of Elements
9. Thermoelectric Power
10. Homogeneity, Parasitic Currents
11. Common Types of Couples
12. Iron-Constantan Couple
13. Copper-Constantan Couple
14. Chromel-Alumel Couple
15. Plat — Pt-Rh. Couple
16. Reference Junctions, Wells
17. Placement of Couples
18. Extension Leads
19. Reference Junction Corrections
20. Thermoelectric Installations
21. Protecting Tubes
22. Lag Coefficient
23. Thermoelectric Indicators
24. Millivoltmeters
25. MV. Action
26. Pyromillivoltmeters
27. Potentiometers
28. Pot. General Principle
29. Pot. Scale Sensitivity
30. Pot. Scale Shift
31. Pot. Ref. Jct. Correction
32. Pot. Advan. and Disad.
33. Resistance Pyrometry
34. Basic Principles of Res. Therm.
35. R.T. Coil Material
36. Wire Size for R.T.
37. Mounts for Coils
38. Protecting Tubes for R.T.
39. Measurement Bridge
40. Dummy Leads
41. Direct Reading Bridge
42. Placement of R.T.
43. General Use of R.T.
44. Range
45. Accuracy
46. Test



Flame Temperature Measurement by the Line Reversal Method.

ITEMS TREATED IN LECTURES SECOND MONTH

1. Thermal Radiation
2. Nature of Thermal Radiation
3. Range of Thermal Radiation
4. Radiation Laws
5. Blackbody, Gray Body
6. Total Emissivity
7. Absorptivity
8. Artificial Blackbody
9. Theory of Radiation Pyr.
10. Stefan Boltzman Equation
11. Radiation Temperature
12. Three Parts of Rad. Pyr.
13. Precautions for Rad. Pyr.
14. Use of Rad. Pyr.
15. Theory of Optical Pyr.
16. Wien's Law
17. Applied Scheme of Opt. Pyr.
18. Morse Thermogage
19. L & N Opt. Pyr.
20. F & F Opt. Pyr.
21. Pyro Opt. Pyr.
22. Brightness Temperature
23. Spectral Emissivity
24. Means of Emissivity
25. Conversion S to T
26. Extension of Range
27. Electric Eye Pyr.
28. Secondary Standards
29. Line Reversal Method
30. Balance Methods of Pressure Meas.
31. Limp Diaphragm
32. Bell Types for Pressure
33. Piston Types for Pressure
34. Bourdon Gages
35. Helix, spiral gages
36. Diaphragm, Bellows Gages
37. Piezoelectric Gages
38. Conductivity Gages
39. Theory of Pres. Therm.
40. Pressure Therm Bulbs
41. Pressure Therm Capillary
42. Gas Properties
43. Ambient Temp. Correction
44. Properties of Liquids
45. Liquid Filled Bulb Position
46. Vapor Type Liq. Properties
47. Vapor Type Bulb Position
48. Vapor Type Amt. of Liq.
49. Rel. Adv. of Pres. Therm Types
50. Uses

Test

ITEMS TREATED IN LECTURES THIRD MONTH

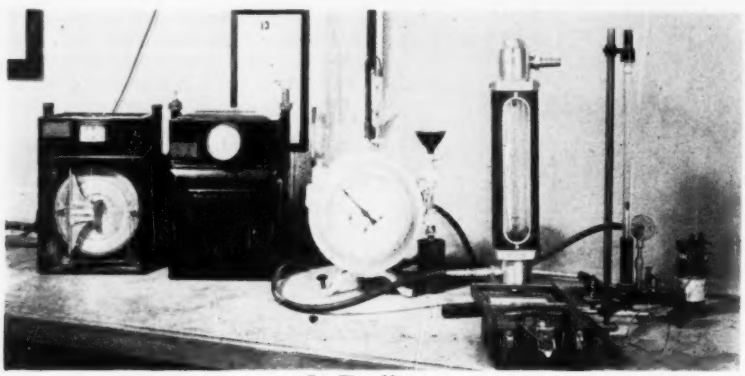
1. Venturi Meters
2. Flow Nozzles
3. Orifice Plates
4. Pressure Taps
5. Orifice Plate Construction
6. U Tubes and Bellows
7. Flow Meter, Steam
8. Flow Meter, Gas
9. Flow Meter, Liquids
10. Pitot Tubes
11. Flow Meter Cycling
12. Blow-out Checks
13. Motion Transmission
14. Gyroscopic Flow Meter
15. Rotameters
16. Area Piston Type
17. Anemometers
18. Volumetric Piston
19. Volumetric Bucket
20. Volumetric Bellows
21. Volumetric Slide Vane
22. Current Types
23. Level Measurement
24. Bubble Type for Level
25. Bubble Type for Density
26. Telemetering
27. Advantages of Various Types
28. Electric Telemetering
29. Current Telemetering
30. Inductive Telemetering
31. Voltage Variation
32. Frequency Variation
33. A-c. Bridge Tele.
34. Selsyn Motor
35. Advantages of Automatic Control
36. Process Lags
37. Instrument Lags
38. Control Mechanism Lags
39. Dead Time

Test

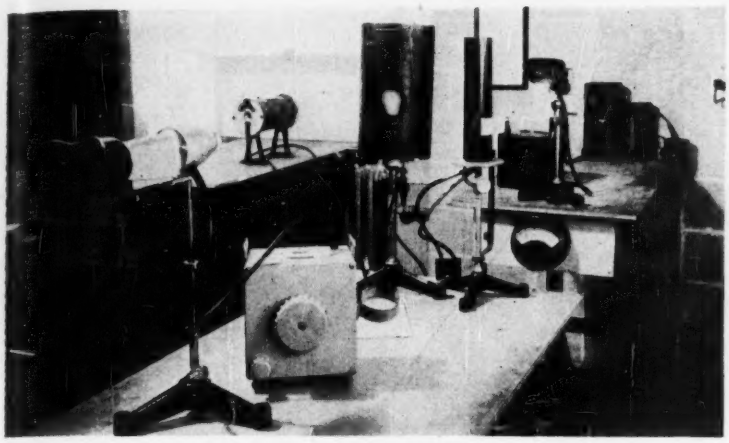
ITEMS TREATED IN LECTURES FOURTH MONTH

1. On-off Control
2. Proportioning Control
3. Proportioning with Reset
4. Floating Control
5. Rangeability of Valves
6. Valve Port Design
7. Balanced Plug
8. Valve Operation
9. Electric Throttlers
10. Self vs. Servo
11. Self-operated Temp.
12. Self-operated Pressure
13. Pressure Boosters
14. Self-operated Level
15. Electric Relays
16. Magnetic Servo
17. Pneumatic Servo
18. Flapper Valves
19. Hydraulic Positioners
20. Flow Control
21. Control Valve Placement
22. Flow Ratio Control
23. Liquid Level Control
24. Feed Water Control
25. CO_2 Control
26. Smoke Control
27. pH
28. Humidity
29. Viscosity
30. Specific Gravity Control
31. Proportional Control Devices

Test



Gas Flow Meters.



Optical Pyrometers and Measurement of Emissivity.

Some time is spent on the proper design of the plant in its relation to its future control. Attention is also given to the problem of providing the proper amount of instrumentation for a maximum financial return on the process.

The laboratory is equipped with many types of measuring and control devices. Included in this apparatus are six temperature controllers of various make and several temperature recorders. Seven flow meters of various types are provided for student experiments. Density and level measuring apparatus is also available in the student laboratory. There is also considerable equipment for calibration.

Fourteen electric furnaces and ovens in the laboratory may be used for calibration and for study of control problems. The laboratory is well supplied with portable measuring instruments such as millivoltmeters and potentiometers.

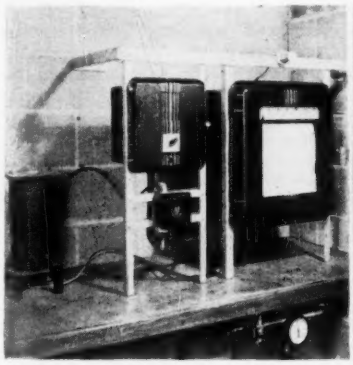
The course consists of two lectures and one three-hour laboratory period per week for one seventeen-week semester. Supplementary to the lectures, "Industrial Instruments for Measurement and Control" by Rhodes is used as a textbook. In addition to the text, "Industrial Process Control" by Eckman and "Automatic Control Engineering" by Smith are available to the student for further study. Bulletins of the Bureau of Standards and various trade bulletins are also provided for reference.

The aim of the course is not to train technicians, but rather to train engineers to the end that they will have the fundamental knowledge necessary to understand the problems of engineering instrumentation. Time is spent on special mechanisms only to acquaint the student with the basic principles of the measurement and control of the particular condition or property.

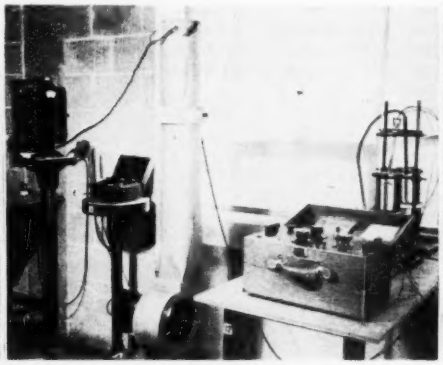
The content of the course is directed to supplying the student with that knowledge which will enable him to choose the proper instruments for the job at hand, to superintend the correct installation of these instruments, to superintend the operation and maintenance, and to determine the proper balance of instrumentation for a maximum financial return on the investment.

In view of the present trend toward complete automatic control of processes, the student is made aware of such trends to the end that he may be prepared to orient his thinking to the rapidly developing changes in design of process devices and their instrumentation.

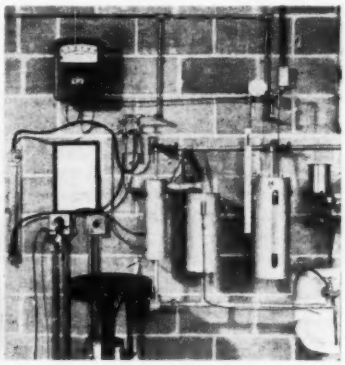
This course is required of all seniors in Chemical and Metallurgical Engineering and is offered as an elective for all other engineering students.



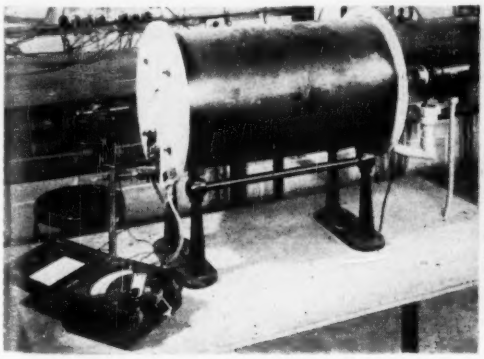
Proportioning and Proportioning-with-reset Controllers.



Calibration and Installation of Resistance Thermometers.



Density and Level Measurements.



Radiation Pyrometer Calibration and Installation.

Calibration and Installation of Thermocouples.

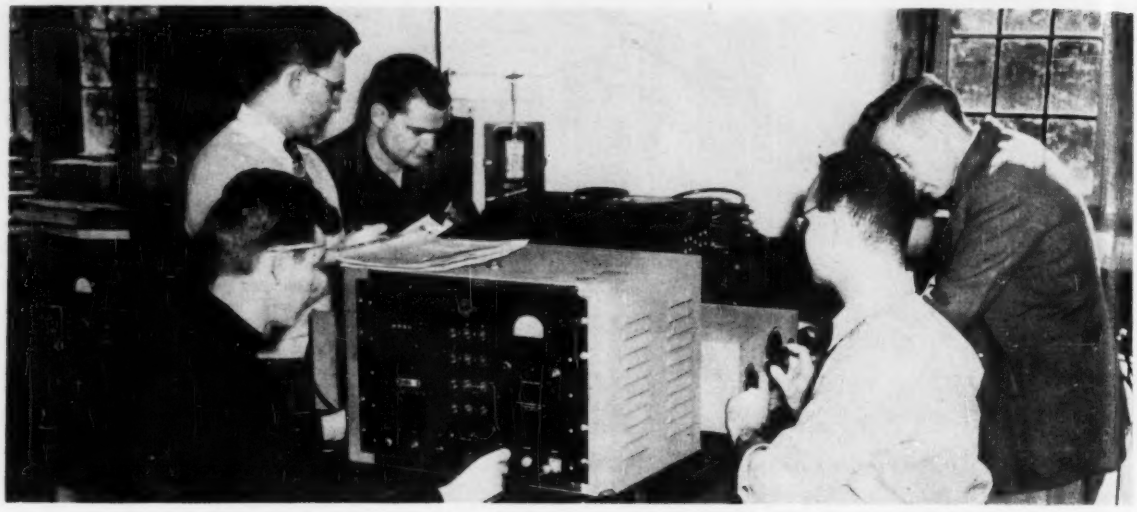


Fig. 1. Laboratory section examines wave-form of audio oscillator prior to calibration against signals from Station WWV, and starts test on new decade scaler.

Concepts *of* Instrumentation *as* Taught *at* The University *of* Tennessee

By PHILIP EWALD, Graduate Assistant, Physics Dep't, University of Tennessee, Knoxville, Tenn.

AT the close of the late war, it became apparent that a specialized course in instrumentation was among the changes needed in the curriculum at The University of Tennessee in order to meet the demands of advancing technology. After considerable thought by all departments concerned and led by the Chemical Engineering Department, it was decided to have the subject taught in the Physics Department, not only because of the long-time interest and activity of this group in instrumentation, or because of the physical nature of the matter, but in order to strategically locate the course to serve all branches of science and engineering. As a result, the University Catalog now carries under the listing of Physics courses the following entry:

> 441-2-3 Instrumentation. Physical Principles of Measurement. Static errors. Dynamic errors. . . . Study of instruments and automatic controls. . . . Two hours and one laboratory period. Three hours credit, each quarter.

The course was developed and is taught by Professor John D. Trimmer, who came to the University after working on instrumentation at M.I.T. for several years under Professor Draper, and at Oak Ridge in the Electromagnetic Isotope Separation Plant and on nuclear pile control. He is author of the forthcoming book "Response of Physical Systems" (John Wiley & Co.) written as a text for the course, and of an article in the October 1949 *Scientific Monthly* on "Instrumentation and Cybernetics." Designed for students with a knowledge of calculus and elementary differential equations, the course has attracted seniors and graduate students in several branches of science and engineering, principally in physics and electrical engineering.

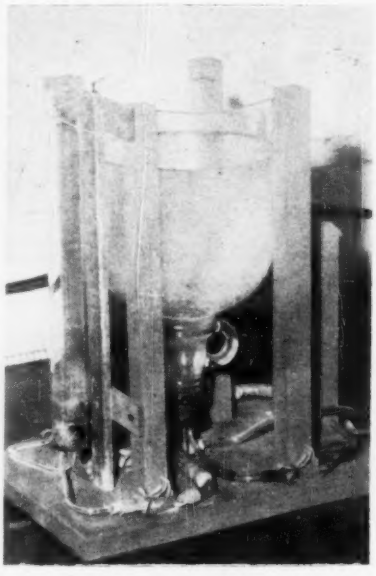


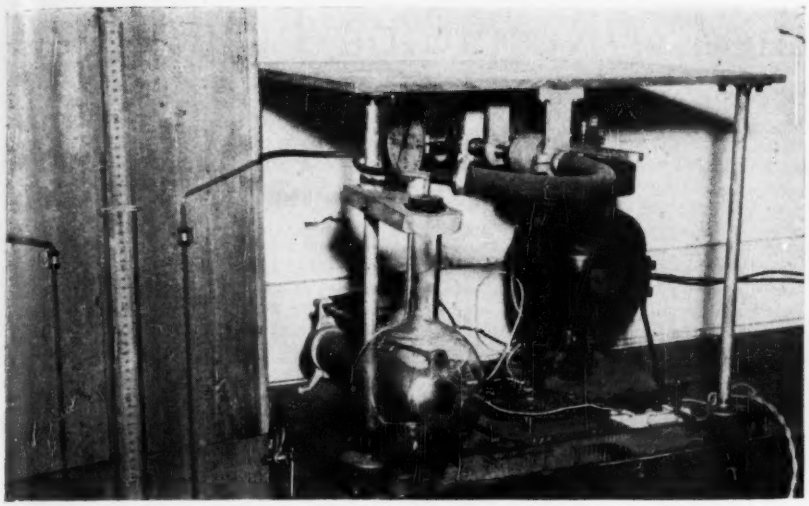
Fig. 2. Hydraulic forcer for producing first-order exponential or step function.

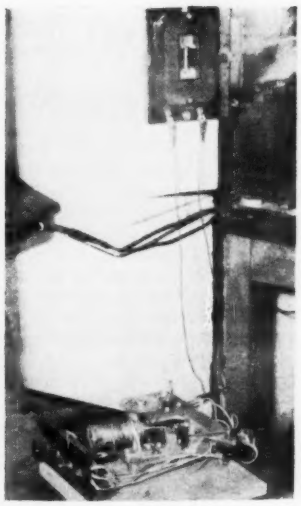
The course material covers three quarters. In the first, measurement is defined, with its limitations and effects on the measured system. Then, there follows a discussion of the three basic instrument specifications: range, efficiency* and accuracy. In connection with accuracy, the concept of random or probable error is studied in detail, including the criteria for stating accuracy of measurements.

The second quarter commences with an investigation of the response of a simple first-order system, such as a capacitance-resistance combination, to a step function, and progresses through more complicated cases such as exponential and sinoidal forcing. The study is repeated for second-order systems, as obtained for example with a capacitance-inductance combination. The idea of feedback is introduced, and the quarter concludes with a mention of higher-order distributed, and non-linear systems.

The third quarter continues with the study of system response, with increased emphasis on feedback. Methods are investigated for obtaining roots of the higher-degree equations involved.

*EDITOR'S NOTE.—We believe that in Dr. Trimmer's course this term does not have the common or "engineering" meaning but is the ratio of the available energy (corresponding to the value of the measured magnitude) to the energy used in the instrument input. In some cases it is expressed as "deflection" divided by "energy," both these terms being narrowly defined. In many cases "efficiency" appears to be synonymous with the measuring property ordinarily called "sensitivity." In a few cases it is used interchangeably with "impedance." We eagerly await the appearance of Dr. Trimmer's book where this and other novel concepts will be disclosed.—M. F. BEHAR





LEFT.—Fig. 3. Motor-driven sinoidal hydraulic forcer. Water or mercury in U tubes simulates second-order system.
RIGHT.—Fig. 4. Motor-driven sinoidal electric forcer. Galvanometer coil simulates second-order system.

and then the concept of stability is considered using an approach similar to that of Routh's Rule and the Nyquist Criterion, but of a simpler nature. This last quarter presents the material which is, of course, needed to understand the operation of controls, regulators, and servomechanisms.

For each two hours of classroom work, there is one two-hour laboratory period. One of the laboratory sections is shown in session in Fig. 1. It is following the established axiom of learning: that there is no better way to learn than by doing. This is particularly true for engineers, and to be able to study the theory of probable error and then demonstrate it on the nuclear radiation counter, or to plot the theoretical response of a feedback amplifier and compare it with the action of an amplifier in the laboratory ties theory to the physical world in a rewarding manner.

Typical of the apparatus used are the forcing systems illustrated in Figs. 2, 3 and 4. All have been built in the laboratory to demonstrate certain types of response. The simplest, and first one constructed, is the hydraulic forcer shown in Fig. 2. It is a first-order system which is linear or non-linear depending on the size of capillary used, and may be used for step or exponential forcing. For this apparatus, the water levels in the jar or standpipe are the "amplitudes" of the system. Fig. 3 shows another hydraulic forcer which imparts a sinoidal action to a U-tube or other system. The apparatus of Fig. 4 is an electrical forcer which imparts, by means of a motor-driven voltage-dividing resistor connected across a battery, a sinoidal emf. to a wall galvanometer which serves in this case as a second-order system.

Closely tied in to the course are several research projects devoted to developing apparatus suitable for demonstration work. Some are carried out by graduate students working toward advanced degrees. An example is shown in Fig. 5 where a "butterfly" motor-driven capacitor, useful in simulating the action of a capacitor microphone, is under test.

While the tenor of this course may seem to be too theoretical for a study of instrumentation, particularly from an instrument user's standpoint, it represents a necessary approach to the subject for scientists and engineers who intend to work on the research and development of modern measuring and controlling instruments. Technology is advancing at such a rapid rate that the only sure way to keep pace with the trend is to attain a thorough grounding in the mathematical and physical basis of the subject and then to add a knowledge of the "hardware" or apparatus to be used in a specific case. To this end, the course has been set up so that when the engineer confronts a measurement and control problem, whether the designation is "automatic-control," "servo-mechanism," "feedback," "supply and demand," "cybernetics," or any other name, he will recognize the same old fundamentals and will be able to proceed accordingly.

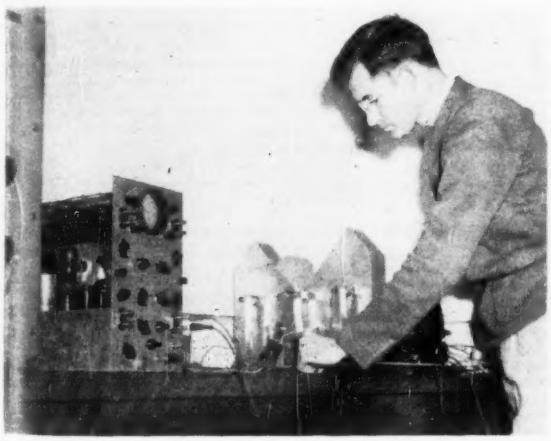


Fig. 5. Graduate student adjusts capacitor-microphone simulator.

Fig. 6. Group checks statistics of emmission from radioactive sample.

The answer was found in a chart paper now called Thermaline, treated

ratchet cut in the drive shaft. The

solution were necessary for satisfac-

A New Method *of* Recording Flight Data

By HENRY SOSTMAN, Senior Engineer, G. M. Giannini & Co., Inc., Springfield, N. J.

INSTRUMENTATION for airborne use involves fundamental design considerations not implicit in laboratory or in fixed-location industrial equipment. Vibration conditions are always present. Accelerations of the order of 10 *G* in any direction may be encountered in piloted craft and may run much higher in pilotless planes and missiles where human toleration of acceleration is not a limit. Ambient temperatures from —76 to +149 F. and pressures from sea-level to 40,000 feet and higher are standard specifications, and transit time from one to the other extreme may be very brief. Measurement is required to a good degree of accuracy over the full range of any one phenomenon while the instrument remains insensitive to all the other conditions of its operational environment. Restrictions which do not apply to function and yet which influence design are those of size and weight, which must be held to a drastic minimum, and limited power supply—commonly direct current.

The past thirty years have seen the challenge of these rigorous conditions met with many rugged and accurate instruments capable of transmitting as electrical signals representations of flight phenomena: airspeed, pressure, altitude, acceleration, vibration, pitch, yaw, and others. The actuated members of these transmitters include voltage dividers, servomechanisms, variable inductors, etc.

The new method here disclosed was designed to provide a means of recording the output of these widely diverse transmitters with an accuracy commensurate to that of the signal. Requirements survey indicated the need for (1) multiple channels; (2) direct input without amplifiers; (3) several chart speeds; (4) continuous, separate and immediately readable traces; (5) small size and light weight; and (6) sturdiness in keeping with hard usage. Furthermore, (7) it was considered desirable to make the embodiments of the new method suitable for use with 28-volt d-c., 115-volt 60-cycle, and 115-volt 400-cycle a-c. power supplies.

D'Arsonval galvanometers were chosen as the stylus-driving elements, since they were felt to give most satisfactory sensitivity and response for their weight and input power. Permanent magnet structure was automatically indicated, for the power demand of multiple field coils would be excessive. The magnetic structure was designed as a flat rectangle to facilitate stacking several units side-by-side in limited space (see Fig. 1). The use of Alnico VI for core as well as pole pieces provides the high gap flux density of 45 kilomaxwells. The moving coil, of Formvar-covered copper wire, is supported on pivots running in jewelled bearings, and to one of these pivots is attached the stylus structure, consisting of two parallel arms of small-bore nickel tubing, flattened in the plane of the paper to provide vertical compliance and lateral stability. The moving element is completely balanced: there is no change in trace amplitude when the recorder is rotated through 360 degrees in any plane.

Galvanometer damping is a compound function. Magnetic damping is provided by winding the coil on a thin copper bobbin which is in effect a single shorted turn of low resistance, and further damping is represented by the frictional impedance of the stylus tip upon the chart paper. The motor structure produces enough torque to permit the use of very heavy restraining hairsprings, which establish a natural frequency above the range of almost all aircraft signals. To answer the need for several channel widths, three separate galvanometers were designed, with full-scale sweep of 0.75, 1.50 and 3.00 inch double amplitude for equivalent signal input. Fundamental characteristics of these galvanometers are given in Table I. Details shown as approximate are so listed because their constants depend upon transmitter as well as recorder circuits. Calibration of the recorder in terms of a given input circuit is both necessary and simple.

Extensive preliminary studies of writing media showed forcefully the need of a new approach to the matter of drawing a line.

Ink, the time-honored medium of industrial recording, is not at home in aircraft; it freezes at low temperatures, froths at high altitudes, spatters under the accelerations of maneuver, blots in excessive humidity, washes away upon submersion. Inked pens require frequent maintenance.

Colored papers coated with a thin skin of wax which is cut through by abrasion or heat offer analogous difficulties in use: wax is gummy at high temperatures and brittle at low.

Charts surfaced with plastic and marked with heat were found to give an excellent trace, but the line was obliterated by even moderate handling.

Paper sensitive to the passage of an electric current was found to represent a fire hazard and, at the light pen pressures necessary for good transient response, carbonaceous material from the paper collected on the stylus and was not rubbed off.

Film was given no consideration, since an important object was to provide an instantly readable trace that would not require the delay of processing, and possible repetition of costly test flights.

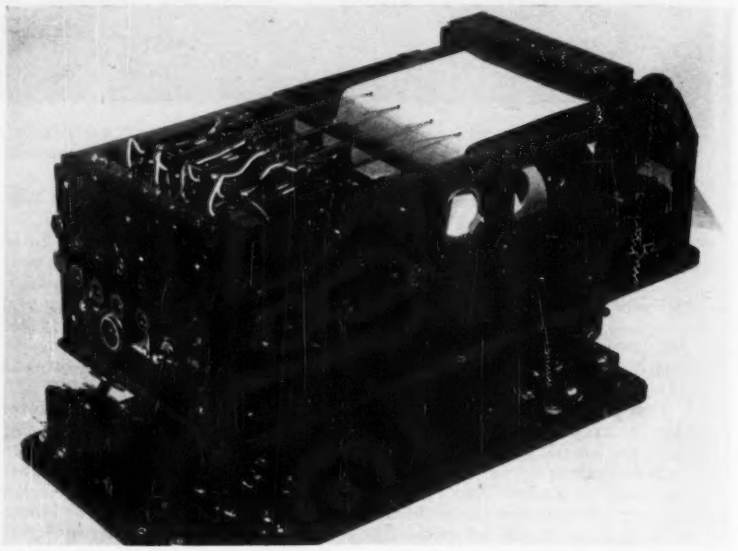


Fig. 1. Experimental but highly-developed embodiment of the new recording method. Cover and galvanometer hood removed to show the four galvanometer arms.

TABLE I.—CHARACTERISTICS

Number	A2022	A2041	A2042
Trace double amplitude, inches	0.75	1.50	3.00
Trace deflection, plus-or-minus inches	0.375	0.75	1.50
Trace width, approximate inches	0.008	0.008	0.008
Trace resolution, approximate inches	0.003	0.003	0.003
Current, approximate maximum milliamperes	10	10	10
Coil resistance, approximate ohms	160	200	240
Natural frequency, cps.	25	18	16
Response: flat within 1 percent to cps.	12	8	8
flat within 10 percent to cps.	18	12	12
Phase shift per cps., degrees	3.2	4.6	4.8
Motor structure torque, inch-pounds-radian	0.15	0.09	0.075

The answer was found in a chart paper now called Thermaline, treated with a coating of a white oxide that reduces to a black oxide at a trigger temperature of approximately 400 F. The resulting trace (see Fig. 2) is a fine black line as permanent as the basic paper stock. The record is completely unaffected by handling, and will withstand weeks of immersion in salt water. The writing stylus is a small sharp cone of sapphire suspended in a miniature heating coil, the leads to which are welded into the supporting arms. Through these, and through the heavy restraining hairsprings, heating current is passed to the tip coil. The tip assembly (Fig. 3) weighs less than 40 milligrams, and has a paper contact area of approximately three millionths of a square inch.

Recorder chart drive is accomplished by a small gear-head motor, stabilized in the d-c. model by a Lee type governor. The motor shaft works into three parallel gearsets of different ratio, which in turn drive the metering roller. Each of the parallel driven gears contains a spring-loaded pawl in its hub. To select a chart speed the drive shaft, which terminates in a knob, is pulled out or pushed in to a position established by detents, and the pawl of the selected driven gear engages a narrow ratchet cut in the drive shaft. The remaining gears are thus free to float upon the shaft. Standard gear ratios drive the paper at speeds of 0.2, 1.0 and 5.0 inches per second, driving the 250 feet of chart in 4 hours, ¾ hour and 8 minutes respectively; but the arrangement is flexible enough to permit the incorporation of almost any group of three speeds. Shifting can be done while the recorder is in full operation.

Fig. 2. The four inkless records are immediately legible without developing. The thermosensitive paper withstands tropical heat without discoloration because the white oxide does not turn black below about 400 F.

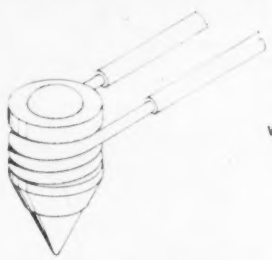


Fig. 3. Enlarged view shows sapphire cone spun into bronze shank around which is wound heating coil. Leads welded into tube assembly support the stylus. Outside diameter of the coil is 0.062. inch.

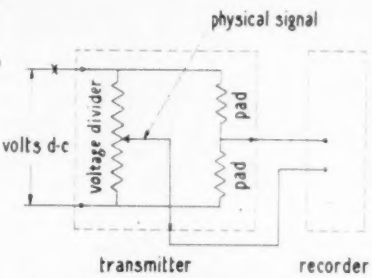


Fig. 4. A recommended input circuit for a voltage-divider transmitter is this Wheatstone bridge arrangement. A rheostat may be inserted at X to calibrate, or an Amperite regulator to stabilize voltage.

A warning light is provided to signal the approach of the end of a roll of chart, and an automatic switch stops the recorder when the paper supply is exhausted. To preclude the chance of a hot stylus standing upon stationary paper, the operational switching arrangement of the instrument is so designed that motor and stylus circuits are interlocked. Throwing either of the two switches on the terminal board to the "on" position starts the chart drive, and switching the second to "on" closes the stylus heater circuit. Throwing either to the "off" position opens the stylus circuit, and switching the other to "off" stops the drive motor. In addition, the heater circuit contains a balancing element to prevent overheating from sudden increases in line voltage.

The use of a d-c. motor in the chart-drive train posed two problems whose solution were necessary for satisfactory performance. The governed motor speed is constant with reasonable voltage fluctuation to plus-or-minus 2 percent, and if the time-axis of the record were defined by chart speed, its accuracy would be accordingly limited. Nor could several recorders (to provide a large number of simultaneous channels) be synchronized to better than these tolerances. A marking stylus was incorporated in the galvanometer bank; a stylus structure similar to the galvanometer writing member, but actuated through an amplitude of approximately 0.05 inch by a solenoid, to write a time or other on-off trace down one margin of the chart. An external time-pulse generator containing an escapement-controlled d-c. motor capable of 0.1 percent accuracy drives a keying arrangement controlling the power to the marker stylus solenoid. To write a record which can be read at a glance, the time pulse generator produces "on" switching at the rate of five pulses per second for one second, then "off" switching at the same rate for the same period, and every twenty seconds a continuous unpulsed line for one second. The time pulse generator may be employed to key the internal marker styli of any number of separate recorders, permitting accurate synchronization of many channels. The marker stylus may of course be keyed from any other switching source.

The d'Arsonval galvanometer, perhaps the fundamental electromechanical movement, is capable of circuit arrangement to register the value of almost any electrical parameter. It is anticipated that the new method will find its most usual use with voltage-divider type transmitters. These transmitters, being compact and reliable sensing elements, lend themselves to a great diversity of measurement. The signal output of a voltage-divider is a change in resistance ratio, and when the voltage-divider is wired as one half of a Wheatstone bridge with the recording galvanometer in the sensing arm (as shown in the circuit diagram, Fig. 4) measurements of a good order of accuracy are possible. Selsyns, Autosyns, and similar position-transmitting devices show change in voltage between any two taps when their shafts are rotated. Directly in the case of d-c. servos and through dry-disk rectifiers for a-c. instruments, the galavanometer in series with a suitable limiting resistance will show these position indications as a record of voltage change. The galvanometers can be used with low-output transmitters such as thermocouples and strain gages with a stage of amplification before the recorder.

In summary, the new method has been designed to write an instantly readable and relatively indestructible trace representing almost any d-c. or low-frequency signal, and to maintain accuracy under the stringent conditions of flight. Primarily intended for aircraft service, it should find application as well in other fields.

Some Application Factors Affecting *the* Regulation *of* pH *in* Industry

By ALLEN L. CHAPLIN, Consulting Engineer

IX. THE REAGENT FEED DEVICE

In general, reagent should be added at a point where it will be uniformly distributed throughout the process liquor in the shortest time possible. If a control tank is involved, there will be less effective short-circuiting in the system by addition of reagent to the inlet liquor pipe with thorough agitation before it enters the tank (Fig. 79). Piping connections from the reagent valve

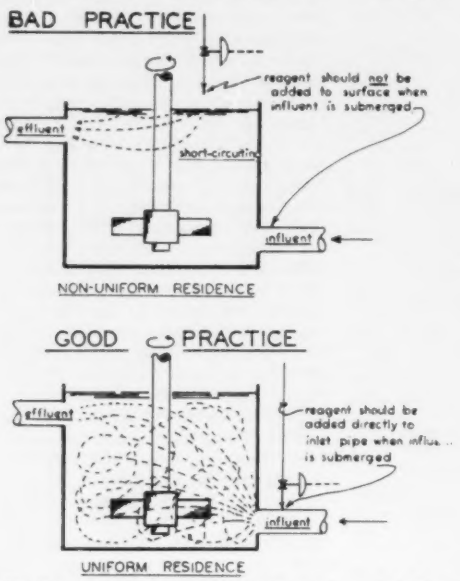


Fig. 79. Reagent should be added directly to submerged influent line of control residence. Introduction of reagent to surface of tank having top effluent enhances short-circuiting.

to point of contact with process liquor must be short as possible to avoid diffusion errors. A long discharge line from the valve to a point beneath the process liquor level, as illustrated in Fig. 80, is to be avoided since diffusion errors result from differing densities of the two liquids, especially at throttled valve positions.

In some cases it is necessary to install the valve at some horizontal distance from the point of reagent addition as illustrated in Fig. 81. To avoid transfer lags in this type of installation, the discharge line should be terminated in a "gooseneck" having a breather connection as shown. This retains a full head of liquid in the line at all times which responds instantly to changes in valve action.

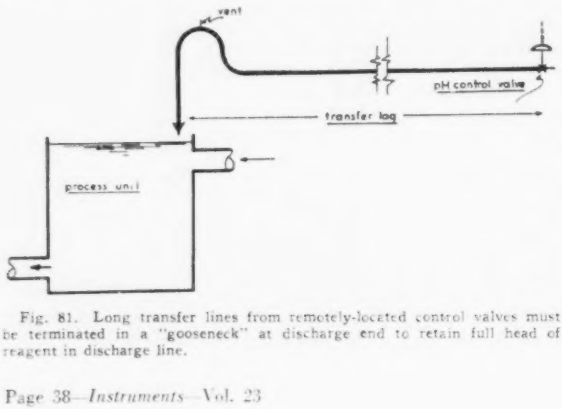


Fig. 81. Long transfer lines from remotely-located control valves must be terminated in a "gooseneck" at discharge end to retain full head of reagent in discharge line.

Valve characteristics have an important bearing on quality of control and it is usually customary to use characterized plug valves of the double-seated type, having V-port or equal-percentage characteristics with a turndown of at least 10 and preferably 50. Single-seated valves are preferred for tight shut-off, while the double seat widens the effective throttling range. Special valves are fabricated from alloy metals, plastics, hard rubber, ceramics and other materials for handling corrosive reagents.

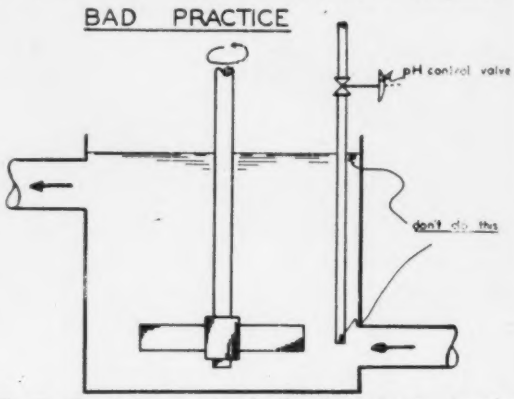


Fig. 80. Oversized reagent transfer lines having low transfer velocity should not be terminated deeply beneath tank liquid level. Diffusion errors may cause unsteady control, particularly if densities differ widely.

Valve positioners are essential on all pH control valves, especially when handling concentrated reagents in a process having high buffer index. It is desirable for the valve to move to its new position as quickly as possible (theoretically instantaneously), and hysteresis or tight packing without a positioner may delay its action. Electric valve drives have the advantage of full power application to the point of balance while air-operated units provide fast response with simplified construction.

Reagent must be supplied to the valve under greater pressure than the process pressure. In many cases this is accomplished by gravity feed from a small reagent head tank installed above the valve which, in turn, may be fed by a pump which circulates reagent from a make-up storage tank through an overflow loop as indicated in Fig. 82. If large volumes of reagent are used, thus

Continued on page 86

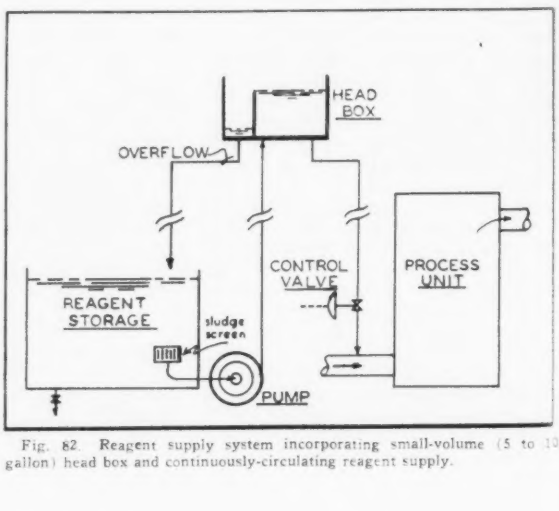
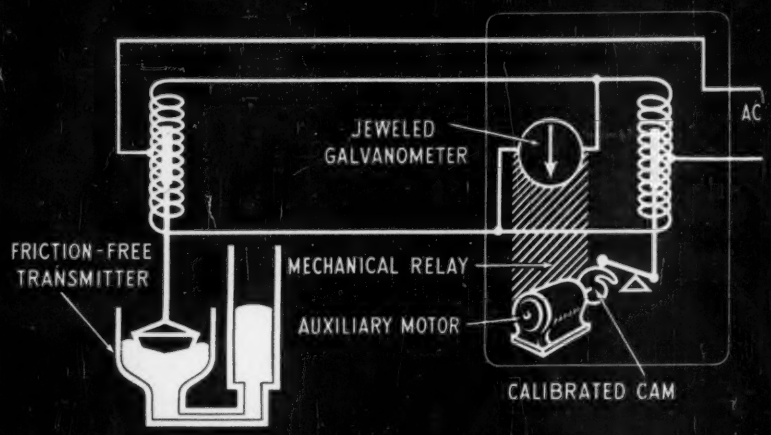


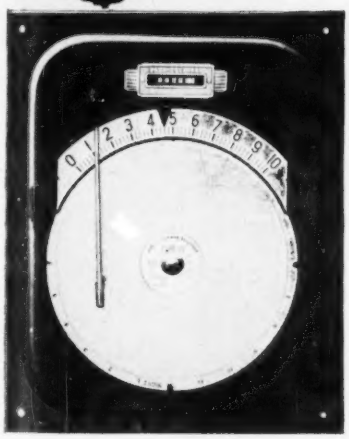
Fig. 82. Reagent supply system incorporating small-volume (5 to 10 gallon) head box and continuously-circulating reagent supply.

simple....powerful....utterly reliable

HAYS-PENN FLOW METER



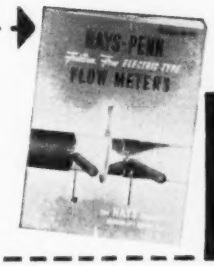
the measuring circuit does none of the operating work



Why does the Hays-Penn Flow Meter *stay accurate* and *last longer?* Simply because the friction-free transmitter serves only as a pilot—actuates an external powerful auxiliary motor which does the work of indicating, integrating and recording.

Friction is eliminated in the manometer—the float rests on the surface of mercury in the high pressure leg, positioning the magnetic core between two reactance coils. There are no stuffing boxes, no bearings, no electric contacts, no solenoid reaction.

For full details on Hays-Penn Flow Meters, for every metering need, send for Publication 43-800.



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The Month's NEW INSTRUMENTS

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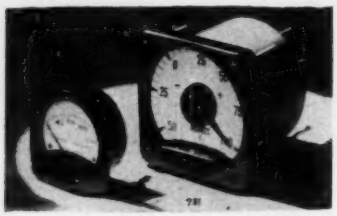
Thermoelectric and Resistance Temperature Indicators

New line of temperature indicators for industrial and laboratory use includes cold-end-compensated thermocouple thermometers (up to 3000 F.)



and resistance (up to 300 F.) Thermocouple instrument is available in two sizes: "Type DO-71" with a 3.5-inch flange and "DW-71" with a 2.5-inch flange. Both types can be supplied in either square or round molded Textolite cases. Resistance instruments are available in two standard types: "DB-15" long-scale instruments; and "DD-6" and "DD-7" six-inch rectangular surface- and flush-mounted instruments.—*Meter & Instrument Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 101 when filling out card.

Miniature Thermostat

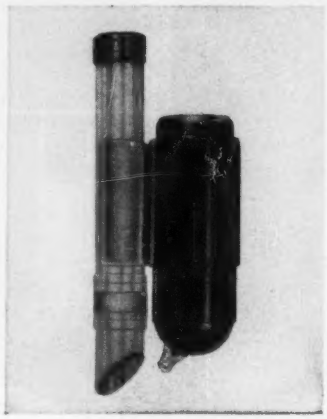
New miniature thermostat is compact; housing measures 1 by 0.31 by 0.25 in. overall, totally enclosed with wire-clinch terminal lugs. Capacity

is 100 watts ac. at 115 volts with n-o or n-c electrolytic-silver contacts. Adjustments from 0 to 400 F. are made by a single adjusting screw. Weight, 0.1 oz. —*George Ulanet Co. 410 Market St., Newark 5, N. J.*

Mention No. 102 when filling out card.

Pocket-microscope Illuminator

New illuminator for use with maker's S-129 pocket microscope, using a standard-size flashlight battery and bulb, directs an oblique beam of light on observed surface, furnishing illumination



of uniform intensity throughout field. It is attached by means of a spring clip and can be removed instantly.—*Buhl Optical Co., Desk T-115, 1009 Beech Ave., Pittsburgh 12, Pa.*

Mention No. 104 when filling out card.

Combustion Apparatus

New combustion apparatus, working with radiant transmission, heats from room temperature to 700 C. in 7 min., and from 750 C. back down in 10 min. A two-speed drive and programming control provide four different 3-phase programs, or two-phase or single-phase as selected. One sample may be burning while other is in preparation. Long furnace length is 7 in., and moving furnace 2 in. Combustion tube up to 14 mm. o.d. is accommodated. Max. temperature is over 850 C. with power of 600 watts.—*E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.*

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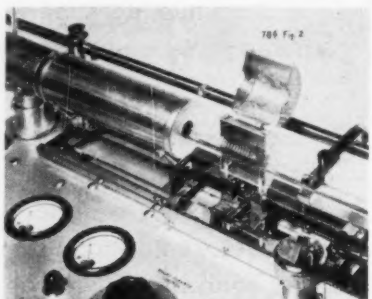
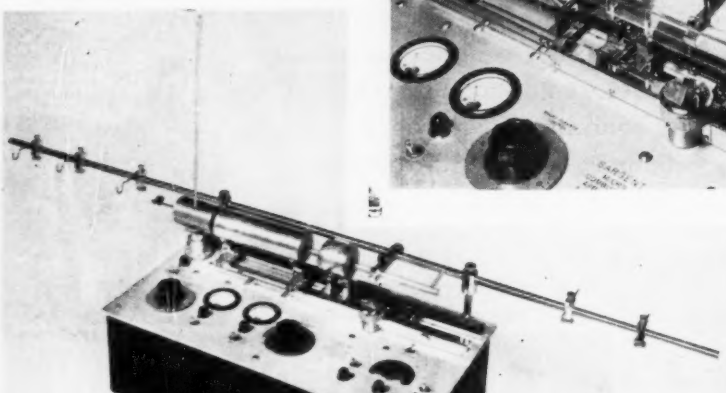
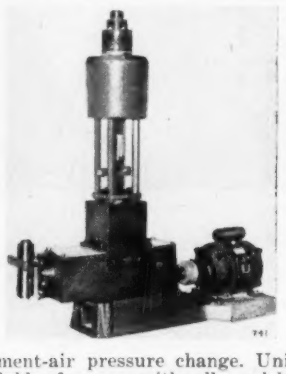




Automatic Controller for Proportioning Pumps

New "Auto-Pneu-Matic" control system for proportioning pumps provides automatic volume change from zero to full displacement in response to in-



strument-air pressure change. Unit is available for use with all models of maker's proportioning pumps, and is suitable for use with all commercial pneumatic systems.—*Process Equipment Div., Lapp Insulator Co., Inc., LeRoy, N. Y.*

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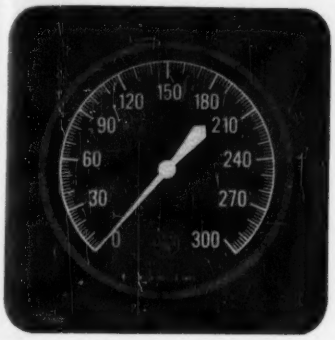
Illuminated Dial Gage

New pressure gage has dial lighted with "black light" that glows in the dark. Case is square and for flush mounting. Dials have a black back-



ground with ultraviolet-phosphorescent pointer, numerals and graduations, or plain white illumination may be supplied. Dimensions and features are maker's standard.—*Helicoid Gage Div., American Chain & Cable Co., Inc., Bridgeport 2, Conn.*

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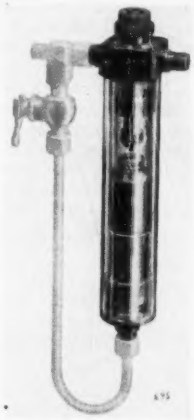
Manostat

New model of maker's manostat, based on Cartesian Diver principle (see *Instruments*, Nov. 1947, page 1032), is designed for pressure and



vacuum control; will maintain vacuum setting even after shutting down system. Available in all-stainless or stainless with plastic-body tube.—*Emil Greiner Co., 20-26 N. Moore St., New York, N. Y.*

Mention No. 107 when filling out card.

Illumination Recorder

New illumination recorder covers a range of 0 to 10,000 foot-candles with an approximately logarithmic scale. Photocell is mounted remotely from recorder. Instrument was developed by U. S. Weather Bureau for recording daylight and is built around standard components, modified to suit measurement. For operation on 115 v. 60 cps.—*Henry A. Gardner Laboratory Inc., 4723 Elm St., Bethesda 14, Md.*

Mention No. 108 when filling out card.

Sulphur Dioxide Recorder

New "Thomas Autometer" continuously records actual concentration of sulphur dioxide in parts per million; records average concentration integrated over a half-hour period; auto-

matically checks its zero reading every thirty minutes; marks off each cubic foot of air sampled. Usual range, 0-5 ppm., covers concentrations of interest in pollution surveys.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Mention No. 109 when filling out card.

Displacement-type Liquid-level Controller

New displacement-type liquid-level controller is said to control liquid level more precisely by balancing changes in buoyancy of an immersed tube with an air-pressure-loaded bellows and by transmitting this pressure to a remotely-located indicating or recording controller. New device, utilizing a forced-balanced system, is said to be particularly adaptable for petroleum and chemical processing.—*Belfield Valve Div., Minneapolis-Honeywell Regulator Co., Broad & Hamilton Sts., Philadelphia 44, Pa.*

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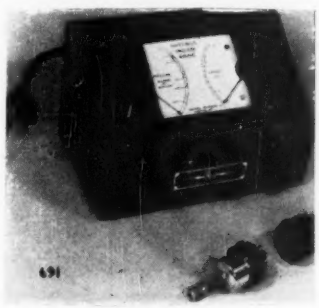
Vacuum Gage

New vacuum gage for range 1 to 1000 microns uses a noble-metal thermopile and a bridge circuit. Gage consists of an electrical indicator and a



small pickup which screws into a 0.125 in. tapped hole in vacuum system. Fast response, interchangeability of pick-ups without recalibration, freedom from outgassing and corrosion, and freedom from damage by exposure to atmospheric pressure are features. Calibration is not affected by connecting cable length.—*Hastings Instrument Co., Inc., Box 1275, Hampton, Va.*

Mention No. 111 when filling out card.

Input Control Unit for Temperature-control Systems

New "Xactline" control unit is used with any standard type or make of pyrometer controller for unusually close temperature variation control.

Unit has kept temperature variations as low as 0.2 F. and power on-off cycles as short as three seconds. Case is 8.5 in. high by 6.25 in. wide by 3 in. deep.—*Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.*

Mention No. 112 when filling out card.

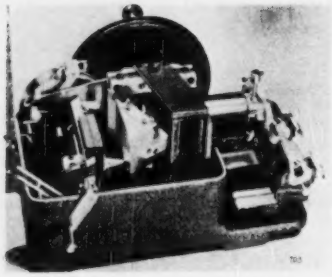
Temperature Controller

New "No. 077" temperature controller for industrial applications is said to be sensitive to "temperature changes as small as one-tenth of one degree." Its range is "between 20 degrees below zero and 300 degrees above." It is said to be immune to vibration, dust and dampness. It utilizes a wire-wound primary element which forms one leg of a Wheatstone bridge circuit. Unbalance of bridge is imposed on an electronic amplifier which amplifies and detects direction of unbalance to actuate either of two output relays, according to direction of temperature change, and thereby control a motor. Announcement states that this principle is being used successfully for temperature control on trains and street cars.—*Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4482 Wague Ave., Philadelphia 44, Penna.*

Mention No. 113 when filling out card.

Ultra-microtome

New "Pease-Baker" adaptation for "Spencer No. 820 Microtome" equipment makes it possible to cut specimens thin enough for electron microscope to penetrate. Method consists of doubly embedding tissue in celloidin and paraffin. After cutting, minute sections are picked up and placed on a microscope slide using needles or a fine brush under a low-power binocu-



lar microscope. Paraffin, and when desirable the celloidin, is then removed and specimen made ready for microscope. Sections one-127,000th in. or less are produced.—*American Optical Co., Southbridge, Mass.*

Mention No. 114 when filling out card.

Programming Control for Burners

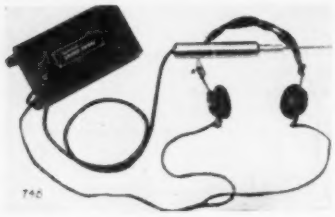
New "Type 24PJ8" programming control automatically starts burner in operation and programs sequence of fuel-valve opening, post-ignition timing, priming, and scavenging. Load

ratings: Burner motor, 1 hp.; pilot duty, 125 va.; Ignition, 250 va.: Fuel-valve solenoid, 100 va.; Gas-pilot valve solenoid, 25 va. Scavenging period, 23 sec. Ambient temp., 32 to 125 F.—*Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.*

Mention No. 115 when filling out card.

Sound Probe

New sound probe localizes sound electronically, bringing it to a focal point, so it may be traced to its source. Probe brings out a natural reproduction of noise, greatly amplified and



without distortion. A particular noise in a motor or bearing may be indentified because all foreign or built-up sounds are absent. Probe is said to be so sensitive that tick of the finest watch is clear and distinct.—*Como-Tex Co., 128 W. Lake St., Chicago 1, Ill.*

Mention No. 116 when filling out card.

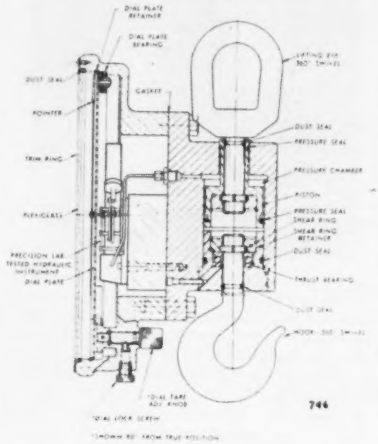
Thermoscopic Pellets, Crayons and Paints

New ratings of maker's "Tempil" pellets indicate 2100, 2200, 2300, 2400 and 2500 F. New ratings of maker's "Tempilstiks" (crayons) are available in corresponding intervals up to 2000 F. "Tempilag" paint is available in similar steps to 1600 F.—*Tempil Corp., 132 W. 22nd. St., New York 11, N. Y.*

Mention No. 117 when filling out card.

Hydraulic Crane Scales

New models of scales described in *Instruments*, Feb. '49, page 147, provide 8, 12, 24 and 30 in. dia. dials in

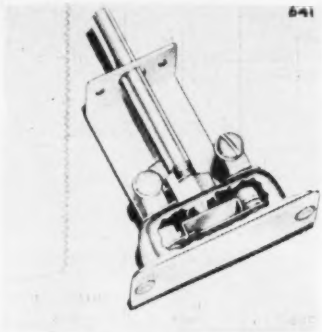


varying capacities up to 25 tons.—*Hydroway Scales Inc., 20624 W. 8 Mile Road, Detroit 19, Mich.*

Mention No. 118 when filling out card.

Thermostats

New "Type R" thermostats are furnished in two basic types: manually adjustable, or preset non-adjustable. Both types are available with a wide variety of terminal arrangements and in many operating ranges up to a

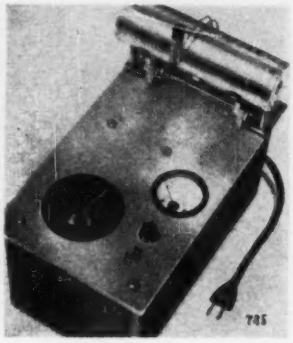


maximum of 600 F. Electrically independent bimetal strip eliminates artificial cycling and unit responds only to temperature changes in controlled device or air surrounding thermostat. Units are precalibrated before shipment in pots simulating actual service conditions.—*Stevens Mfg. Co., Inc., Mansfield, Ohio.*

Mention No. 119 when filling out card.

Combustion Furnace

New combustion furnace, equipped with a quick-opening and closing reflecting shell, permits tube filling to cool while furnace remains in place.



Helical chromel-wire element operates at temperature near that of tube filling. Max. temperature is 850 C. at 300 watts. Max. tube dia. is 14 mm. Furnace height is 9.5 in.; length of panel is 12 in.; case height is 6.63 in. and weight is 21.5 lbs.—*E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.*

Mention No. 120 when filling out card.

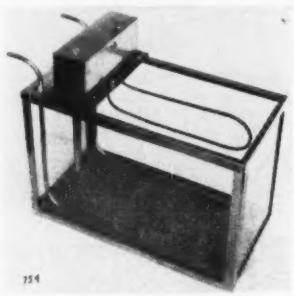
Laboratory Furnace

New "Models VH-48 and VK-48" furnaces are 10 by 8 by 18 in. and made for temperatures up to 1850 F. First model permits manual setting of power input at any point from 5 to 100 percent of full rating. Operating with a control pyrometer, both high and low temperatures may be held at close limits. Second model is designed for controlling pyrometer operation but without auxiliary control equipment.—*Cooley Electric Mfg. Corp., 38 South Shelby St., Indianapolis, Ind.*

Mention No. 121 when filling out card.

Laboratory Water Baths

New "Items V-O, V-4, and V-5" constant-temperature baths are designed for a variety of applications. "Item V-O" is aquarium type 18 by 9.5 by 12.5 in., 8 gallons capacity with



thermoregulator, heating element and coolant tube. "Item V-4" is of stainless construction 22 by 9 by 8.5 in., capacity 6 gallons, and is specially designed to hold "No. 4 Ford type" viscosity cups. "Item V-5" is same, but designed for general use.—*Henry A. Gardner Lab., Inc., 4723 Elm St., Bethesda, Md.*

Mention No. 122 when filling out card.

Laboratory Water Bath

New water bath, 15 in. diameter by 7 in. high, has a Monel exterior and tinned-copper interior. It employs two immersion-type heaters, either or both

of which can be used. Concentric rings for various sizes of flasks and a test-tube holder for up to 14 tubes are provided. A bottle-feed device prevents bath from boiling dry for as long as 10 hours on low heat and 4 to 5 hours on high heat. Weight, 24 lbs.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.*

Mention No. 123 when filling out card.

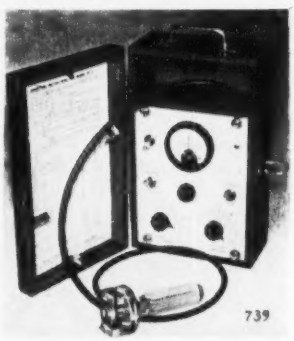
Laboratory Hot-plate

New "Temco" laboratory hot plate is available in 12 by 12 and 12 by 24 in. sizes. Temperatures can be maintained within close limits over range 140 to 850 F. and elements are of flat type which prevent cold spots. For 115 or 230 volt operation.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 124 when filling out card.

Moisture Tester for Lumber

New "Model DC-2" instrument for testing moisture content in lumber utilizes a microammeter with dual ranges from 6 to 28 percent and from

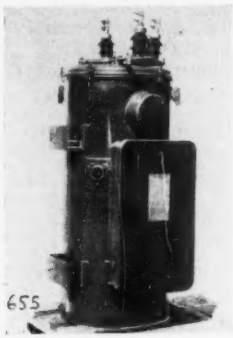


6 to 9 percent to give accuracy, particularly in the low ranges. Instrument employs megohm bridge and null principle. Temperature-correction tables are furnished, permitting readings from 40 to 240 F. Weight is 5 pounds, dimensions 10 by 6 by 4 in.—*Moisture Register Co., 133 No. Garfield Ave., Alhambra, Calif.*

Mention No. 125 when filling out card.

Voltage Regulator

New "Type ML-8" voltage regulator supersedes "Type ML-4" step voltage regulator. It provides a total of 10 percent regulation in eight 1.25-percent steps, in any of the following combi-

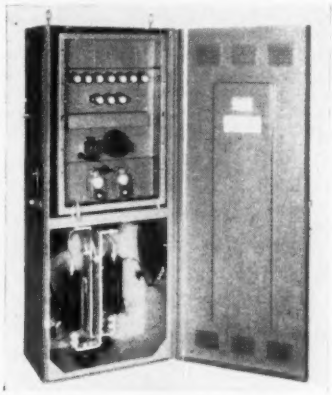


nations: 10 raise, 7.5 raise to 2.5 lower, 5 raise to 5 lower, 2.5 raise to 7.5 lower or 10 percent lower. Unit is available in selected kva sizes in 2500; 5000; and 7620-volt ratings and corresponding Y-connected voltages and permits increase in current-carrying capacity up to 160 percent for connection arrangement of 5 percent raise to 5 percent lower.—*General Electric Co., Schenectady, N. Y.*

Mention No. 126 when filling out card.

Resistance Welding Controllers

Two new all-electronic high-speed resistance welding control equipments, for synchronous and non-synchronous operation, have no moving parts in power and control circuits except initiation and solenoid relays. Basic control panel consists of plug-in Rectox

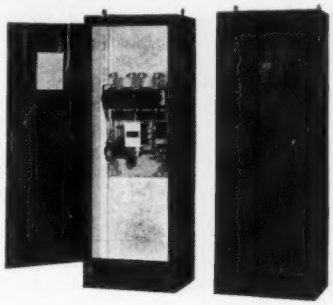


rectifier tube firing panel (for non-synchronous units) or a heat-control firing panel (for synchronous units); also sequence weld timer which controls squeeze time, weld time, hold time, and off time for a single impulse spot welding. Substitution of a precision weld-time panel for a sequence weld timer provides synchronous precision control when heat control panel is used. Auxiliary control panels are available for nine different purposes.—*Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.*

Mention No. 127 when filling out card.

Solenoid Starters

New "Sizes 6 and 7" of "Bulletin 709" a-c. across-the-line solenoid starters have ratings in "Size 6" of 600 amp. and 200 hp. at 220 v., or 400 hp. at 440-550 v., and in "Size 7" of

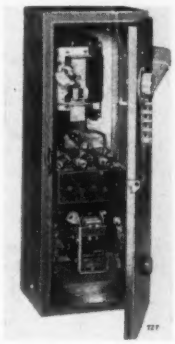


900 amp. and 300 hp. at 220 v., or 600 hp. at 440-550 v. Both models are smaller than conventional starters, steel cabinet requiring only 58 percent of usual floor space.—*Allen-Bradley Co., Milwaukee, Wis.*

Mention No. 128 when filling out card.

Motor Starter

New circuit-breaker type combination starter is designed for control of polyphase motors, 1 to 100 h. p. Interlock prevents opening door when breaker is "on", although an author-

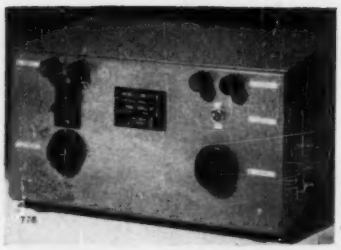


ized person can release interlock for inspection. Self-aligning handle indicates true position of breaker. Operating handle can be locked "on" or "off" with padlocks of varying sizes. Thermal (coilless) magnetic circuit breaker is non-tamperable and can be quickly reset.—*Industrial Controller Div., Square D Co., 4041 N. Richards St., Milwaukee 12, Wis.*

Mention No. 129 when filling out card.

Magnetic Amplifier

New "Type 63-1" d.c. to d.c. magnetic amplifier (developed in London by Electro Methods Ltd.) has a gain constant within 2 percent with a 10 percent change in line voltage, and a zero drift over several weeks within 50 microvolts referred to input terminals. Max. power gain is 14,000, voltage gain 27, and transconductance 5 million micromhos with load resistance of 3 ohms. Max. output current is 300 ma. Amplifier makes possible use of standard indicating or record-



ing milliammeters with thermocouples or thermopiles. Reliability makes unit suitable where vacuum-tube amplifiers would be questioned.—*Trans-Sonics, Inc., Bedford Airport, Bedford, Mass.*

Mention No. 130 when filling out card.

Oven-temperature Tester

New oven-temperature tester consists of a 3.5 in. square-flange millivoltmeter mounted in a leatherette-covered case with a compartment for storing thermocouple leads and as-

sembly. Leads are of color-coded iron-constantan wire, five feet long. Welded junction is surrounded by a radiation shield. A spring clip is attached for clamping thermocouple to oven grill. Instrument has a scale range of 0 to 650 F. and a scale length of 2.46 in. Accuracy at any set point is plus or minus 2.5 percent of full-scale value.—*Meter and Instrument Divs., General Electric Co., Schenectady 5, N. Y.*

Mention No. 131 when filling out card.

Magnetic Micrometer

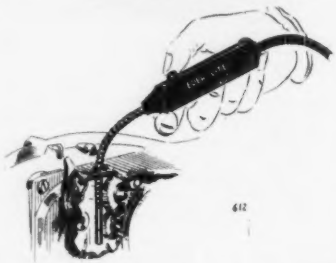
New "Magnifying Micrometer" will measure coating thickness if either base or coat is magnetic, or if both are magnetic but of different permeability. A micrometer indicates tension neces-

sary to separate a small built-in magnet from surface. Accuracy is within 10 percent for coatings thicker than 0.001 in. Calibration gages are available in non-magnetic coating on magnetic base for thicknesses from 0 to 0.08 in., and in nickel on steel or brass, 0 to 0.005 in.—*Krouse Testing Machine Co., 573 E. Eleventh Ave., Columbus 3, Ohio.*

Mention No. 132 when filling out card.

Inspection Lamp

New "Eder-Lite" miniature inspection lamp for hard-to-get-at places has a 110-120 volt transformer used as a handle with a built-in switch for intermediate and constant inspection. Maximum diameter of flexible extension bulb is 0.28 in. Extensions are available in lengths of 4 to 36 inches,

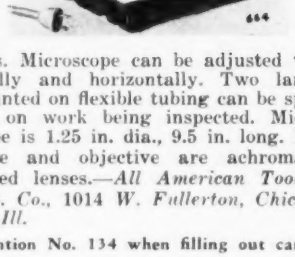


insulated for inspection of or between electrical wirings. Light bulbs are available in metal mounts for a forward glare-free and concentrated illumination or an exposed bulb for forward and side illumination.—*Eder Instrument Co., 1849 N. Halsted St., Chicago 14, Ill.*

Mention No. 133 when filling out card.

Surface Plate with Inspection Microscope and Illuminators

New illuminated layout plate with 16 power microscope for parts to be minutely examined or inspected features ribbed cast-iron layout plate precision ground to 0.0005 in. of true flat-



ness. Microscope can be adjusted vertically and horizontally. Two lamps mounted on flexible tubing can be spotted on work being inspected. Microscope is 1.25 in. dia., 9.5 in. long. Eye piece and objective are achromatic coated lenses.—*All American Tool & Mfg. Co., 1014 W. Fullerton, Chicago 14, Ill.*

Mention No. 134 when filling out card.

Dial Micrometer

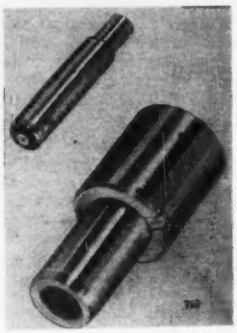
New hand-model micrometer has been designed for portability. Dial is glass covered, 2.75 in. dia., graduated in thousandths of an inch. Anvil permits calipering of thicknesses up to

one-half inch on sheet stock or fabricated pieces, and can be supplied in several diameters and with flat or spherical ends. An external adjustment is incorporated for maintaining dial indicator at exact zero. Lever is located for easily raising anvil for insertion of material to be measured. Anvil descends with even pressure, approximately 7 to 9 psi. (TAPPI standard).—*E. J. Cady & Co., 134 N. LaSalle St., Chicago 2, Ill.*

Mention No. 135 when filling out card.

Air-gaging Spindles

New blade-contact type air spindles for column and dial type "Precisionaires" enable an instrument-type check to be made of practically any hole regardless of finish, interruptions or



size. Spindles consist essentially of a hardened-steel body slightly smaller than minimum hole size, with a hardened-steel contact blade either pivoted or floating, action of which controls flow of air through jets. Minimum size of single-blade spindles starts at approximately 0.375 in. dia. Holes having a surface finish rougher than 75 to 100 microinches can be measured accurately for out-of-round and taper as well as for diameter.—*Sheffield Corp., Dayton 1, Ohio.*

Mention No. 136 when filling out card.

Instrument Oiler

New "Hypo-Oiler" features visible oil reservoir, extra long hypodermic-type needle for reaching inaccessible

parts, and light-film or drop feed depending on pressure used.—*Gaunt Industries, 3521 N. Broadway, Chicago 13, Ill.*

Mention No. 137 when filling out card.

Inspection Magnifier

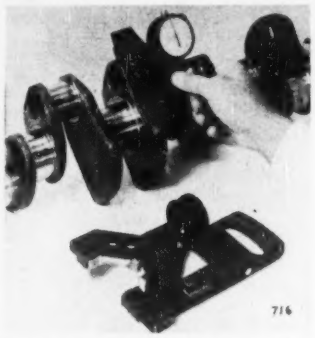
New "Magnalite" consists of a 5-inch lens set in a plastic head with 2 fluorescent lights built in on underside. Flexible-arm mountings permit instant

adjustment leaving both hands free to work. Special machine mounts can be made to specifications.—*Haas Corp., Mendon, Mich.*

Mention No. 138 when filling out card.

Snap Gage

New dial-snap gage features radius guides adapted to maker's standard model gage for checking parts with fillets or close to shoulders. Gage is



specifically designed for checking crankshaft grinding on machine. It has indicator graduations of 0.0001 in. Indicator may be moved to clear any eccentric throw.—*Nilsson Gage Co., Inc., Poughkeepsie, N. Y.*

Mention No. 139 when filling out card.

Container for Liquid Hydrogen

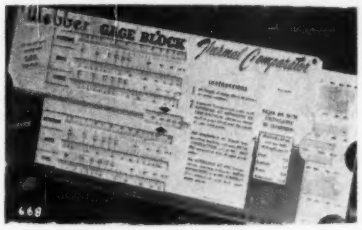
New container for storage and transport of liquid hydrogen and liquid helium is made of three concentric-copper spheres. Inner and outer spheres form a conventional vacuum flask, with facing-interior surfaces

polished to a mirror-like finish. Between them is placed a third sphere, highly polished on both sides, which acts as a radiation shield. This shield is connected to inner sphere of a smaller side flask for containing liquid nitrogen. Containers are available in 10, 25 and 50 liter capacities with side flasks holding 5, 15 and 25 liters respectively.—*Hofman Laboratories, Inc., 212 Wright St., Newark 5, N. J.*

Mention No. 140 when filling out card.

Calculator for Differential Linear Expansions

New "Thermal Comparator" slide rule gives instant reading of difference in expansion between gage blocks and work at various shop temperatures. User sets up gage-block measurement in



small window and obtains a reading that will indicate difference of expansion or contraction between block and work at 68 F. Upper half of instrument is for use with steel blocks and lower with carbide.—*The Webber Gage Co., 12900 Triskett Road, Cleveland, Ohio.*

Mention No. 141 when filling out card.

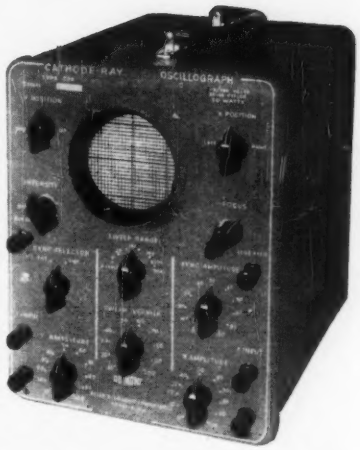
Cathode-ray Oscilloscopes

New "Types 304 and 304-H Cathode-ray Oscillographs" replace "Type 208-B." Except for higher accelerating potential of the "Type 304-H," types are identical. Recurrent and driven sweeps are variable from 2 to 30,000 cps. Slow sweeps, of 10 seconds or more, are available by connection of external capacitors between X-input terminals on front panel. Vertical deflections may be expanded to four times full-screen diameter; horizontal deflections to five times full-screen diameter. Any portion of a fully-expanded pattern may be centered on screen. Higher accelerating potential of "Type 304-H" facilitates use of long-persistence screens. Writing rates as high as 2.8 inches per microsecond may be photographed using "Type 314-A Oscillograph-record Camera" with f1.5 lens. —*Allen B. Du Mont Laboratories, Inc., 1000 Main Avenue, Clifton, N. J.*

Mention No. 142 when filling out card.

Cathode-ray Oscilloscope

New "Type 292" 3 in. cathode-ray oscilloscope weighs 21 lbs., and measures 10.88 by 8.13 by 11 in. Input signals of 0.4 rms volt and 0.56 rms volt will produce 1 in. deflection on vertical and horizontal axes, respectively. X-axis and Y-axis amplifiers supply respective pairs of deflection plates with voltages 180 degrees out of phase. Linear time-base generator provides

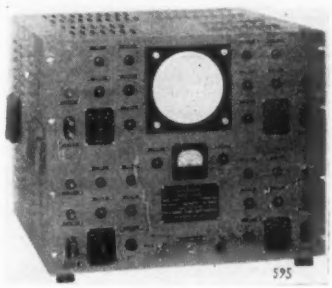


sweep frequencies from 8 to 30,000 cps, synchronized with either vertical amplifier or some external source.—*Instrument Div., Allen B. DuMont Labs., Inc. 1000 Main Ave., Clifton, N. J.*

Mention No. 143 when filling out card.

Four-channel Oscilloscope

New "Model H-43" cathode-ray oscilloscope can indicate as many as four variables on a single 5-in. flat-face tube; has been designed primarily for use with a continuous film type of recording camera. Cathode-ray tube operates at 4500 volts over-all acceleration. Photographically actinic P11 is normally supplied; other phosphors such as P5 (very short decay time) or P2 (high-voltage actinic) are also



available. Separate focus, intensity, and positioning controls are provided in each of four channels, and positioning in both horizontal and vertical directions is possible. Signal amplifiers have a frequency range from 0 to 200 kc. and a gain of about 120. Horizontal deflection can be measured in terms of volts by means of a direct-reading calibrator. Power-supplies are contained in oscilloscope cabinet and require a primary supply of 105-120 volts, 50-60 cps. Power consumption is 200 watts.—*Electronic Tube Corp., 1200 E. Mermaid Lane, Philadelphia 18, Pa.*

Mention No. 144 when filling out card.

Five-gun Cathode-ray Tube

New "55JG" tube with five independent electron guns is added to "H-21" two-gun oscilloscope (described in our Nov. issue, pages 1021-22) and to "H-43" four-gun oscilloscope (see preceding item). Guns are of zero first

Elapsed time intervals can be measured down to 1/1000th second with a

STANDARD PRECISION TIMER

The world's most accurate (and rugged) time measuring instrument. Available in 8 models as shown below:

MODEL	READS	TOTALIZES	ACCURACY
S-100	1/5 sec.	6000 sec.	± .1 sec.
S-60	1/5 sec.	60 min.	± .1 sec.
SM-60	1/100 min.	60 min.	± .002 min.
S-10	1/10 sec.	1000 sec.	± .02 sec.
S-6	1/1000 min.	10 min.	± .0002 min.
S-1	1/100 sec.	60 sec.	± .01 sec.
MST	1/1000 sec.	.360 sec.	± .001 sec.
MST-500	1/1000 sec.	30 sec.	± .002 sec.

Manually and Electrically Operated Portable Cases or Panel Mounting optional changes to conform to customers' requirements.

Special Timing Problem. **Our engineers are ready to consult with you, and design timers to meet special timing problems.**

OTHER PRODUCTS

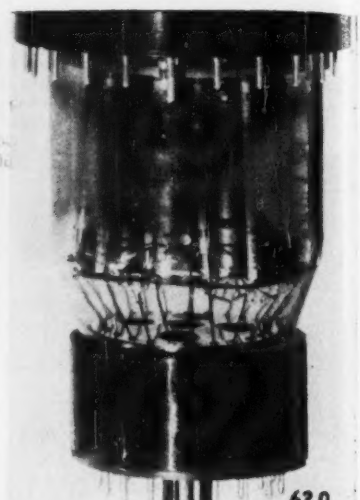
Standard Chrono-Tachometers, Custom-built Laboratory Test and Distribution Panels, School Time Program Systems, Hospital Doctor Paging and Nurse Call Systems.

WRITE FOR BULLETIN NO. 153

STANDARD

THE STANDARD ELECTRIC TIME CO.

93 LOGAN STREET **SPRINGFIELD, MASSACHUSETTS**



anode type with separate heater, cathode, grid, and focussing anode connections to 27-pin base. Deflection plates have separate connections to 22-pin ring around tube base, 13.25 in. from 5-in. flat-face screen. Undeflected beam from each of guns, which are arranged in circle about tube axis, strikes center of screen, which is available in standard phosphors.—*Electronic Tube Corp.*, 1200 *E. Mermaid Lane, Philadelphia* 18, *Pa.*

Mention No. 145 when filling out card.

Oscilloscope Carriage

New "Type R-500 Scope-Mobile" provides a sturdy yet mobile support for oscilloscope, with 20-degree tilt-back. A blank panel, 11 x 15 in., front-

ing a mounting space of approx. 1.5 cu. ft., allows for auxiliary built-in equipment. This space is ventilated by louvres. A power input connector and three convenience outlets are located at back. A felt-lined drawer provides handy storage of cords, probes, tools, etc. Open shelf, 17 x 24 in., is topped with battleship linoleum.—*Tektronix, Inc.*, 712 *S. E. Hawthorne Blvd, Portland* 12, *Ore.*

Mention No. 146 when filling out card.

Megohmmeter

New "Model 29" megohmmeter, imported from England, covers the range 0.3 to 20 million megohms in 6 decade ranges. Test voltages of 85 and 500 d.c. are provided with short-cir-

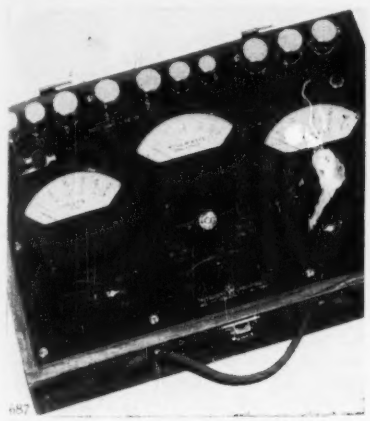
jigs, etc.; two widely separated push buttons that must be depressed to maintain high voltage continuously energized. For 117 volts, 50-60 cps., 225 volt-amps. Ripple is less than one percent.—*Beta Electric Corp.*, 1762 *Th*[illegible]

cuit currents limited to 5 and 2.5 ma. respectively. A 6 in. mirror-scale galvanometer serves as indicator. Charging delay is about 1.5 sec. Power consumption is about 35 watts on 115 or 230 v. 60 cps. line.—*Herman H. Sticht Co., Inc., 27 Park Pl., New York, N. Y.*

Mention No. 147 when filling out card.

Industrial Electrical Analyzer

New "Model 247" portable analyzer measures electrical input to industrial loads. Ranges are: volts 150-300-600; amps. 5-25-125; and single-phase kw. ranges with basic range of 0.6 up to max. of 60 in steps. Amps and kw. may be extended with 5 amp. current trans-

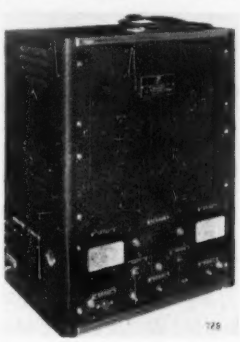


formers. Unit may be used on single-phase 2 and 3 wire, two-phase, and three-phase 3 and 4 wire systems. Accuracy of volt and ammeter is 1 percent and of wattmeter is 1.5 percent. Unit weight is 13.5 lb.; leads and case are 9 lb.—*Instrument Laboratories, 315 W. Walton Pl., Chicago 10, Ill.*

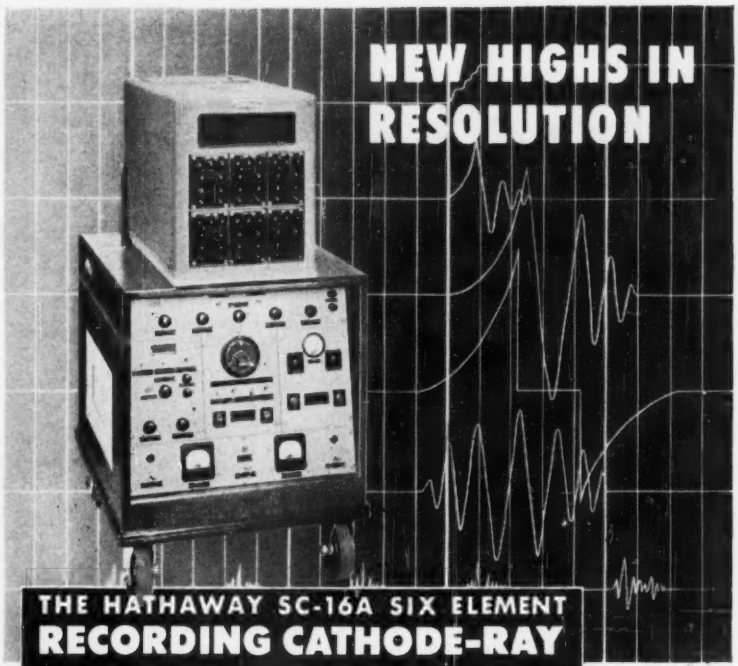
Mention No. 148 when filling out card.

Power Supply for Breakdown Testing

New "Model 224" power supply can provide voltages up to and slightly above 40 kv. d.c., with currents up to 200 microamperes. Unit can be short circuited continuously without injur-



ing any components. A kilovoltmeter indicates voltage at load. Safety features include: Output-voltage shorting solenoid when power is removed; internal interlocks on all doors; provision for external interlocks on test



THE HATHAWAY SC-16A SIX ELEMENT
RECORDING CATHODE-RAY
OSCILLOGRAPH

NEW HIGHS IN RESOLUTION are obtained by this new oscillograph because of its unusually HIGH FREQUENCY RESPONSE and HIGH CHART SPEED...designed for recording fast transients and continuous phenomena.

FREQUENCY RESPONSE 0 to 200,000 cycles per second
RECORDS up to 1000 ft. long at speeds up to 600 inches per second
RECORDS up to 10 ft. long at speeds up to 6000 inches per second
WRITING SPEED above 100,000 inches per second

Note these additional unusual features.

- SIX ELEMENTS with convenient interchangeable lens stages for 1, 2, 3, or 6 traces on full width of chart.
- INTERCHANGEABLE RECORD MAGAZINES for CONTINUOUS RECORDING on strip chart, either 6 inches or 35mm in width up to 1000 feet in length, DRUM RECORDING for short, high-speed records, and STATIONARY CHART for very short transients.
- PRECISION TIMING EQUIPMENT, tuning fork controlled, for 1-millisecond or 10-millisecond time lines.
- Crystal-controlled Z-AXIS MODULATION for 1/10 millisecond time marks.
- QUICK-CHANGE TRANSMISSION for instantaneous selection of 16 record speeds over a range of 120 to 1.
- AUTOMATIC INTENSITY CONTROL.
- CONTINUOUS SWEEP OSCILLATOR which permits viewing as well as recording.
- Single-pulse LINEAR OSCILLATOR for recording transients on stationary film. The record can initiate the transient to be recorded, or the transient can initiate the record.

Each recording element is a complete unit, fully housed, which can be instantly inserted or removed. Recording element contains high-intensity cathode-ray tube, and both AC and DC amplifiers. Control panel is located on outside end.

FOR FURTHER INFORMATION, WRITE FOR BULLETIN 2 G-1-H

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hermetic seal with solder-sealed terminals and crystal; as a shielded or unshielded instrument. Length of the scale arc is 1.3 in.; maker will furnish special scales to meet user's requirements. Feature is number of ranges

TYPE B
HIGH PRECISION

Kester Solder

Kester engineers, with over 100,000 different types and sizes of solder available, will specify the right flux-core solder that will give maximum efficiency and economy to the job.

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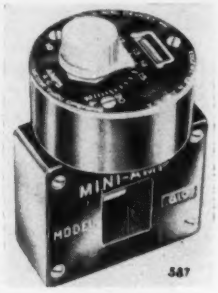
jigs, etc.; two widely separated push buttons that must be depressed to maintain high voltage continuously energized. For 117 volts, 50-60 cps., 225 volt-amps. Ripple is less than one percent. —*Beta Electric Corp.*, 1762 *Third Ave., New York* 29, *N. Y.*

Mention No. 149 when filling out card.

Connectionless Ammeter

New "Model 810 burnout-proof" ammeter is rugged enough to be tossed into tool kit without damage. Current-carrying wire is slipped through open-

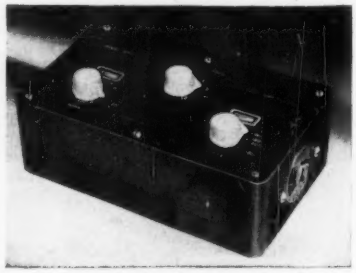


ing in case of instrument and knob is turned until indicator light extinguishes, whereupon current is read in amperes directly off dial. Range may be changed by increasing number of turns through opening. Scale range is 10-24 amperes, which may be extended down to 0.1-0.24 ampere. For 60 cycle a.c.—*Industrial Devices, Inc., Edgewater, N. J.*

Mention No. 150 when filling out card.

Circuit Tester

New "Model 900" volt-amp. tester employs two neon indicators which extinguish at volt. and amp. readings indicated by adjustable knobs. A mul-



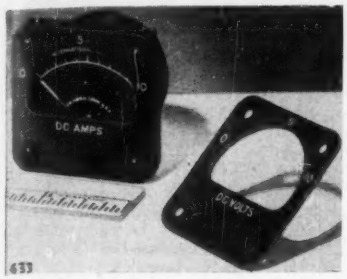
tiplying switch provides for expansion of range indicated on ammeter scale. Tester distinguishes between a.c. and d.c. Dimensions are 3.75 by 6.25 by 2 in.; weight 26 oz.—*Industrial Devices, Inc., Edgewater, N. J.*

Mention No. 151 when filling out card.

Electrical Indicating Instruments with Interchangeable Face-plates

New 1.5-in. diameter panel electrical instrument with interchangeable face plates can be used for several ranges by adding external accessories and by changing face plate. It meets Government specifications; can be supplied with either a water-tight seal or a

hermetic seal with solder-sealed terminals and crystal; as a shielded or unshielded instrument. Length of the scale arc is 1.3 in.; maker will furnish special scales to meet user's requirements. Feature is number of ranges available. D-c. self-contained instrument is said to range from 50 to 500 microamperes; from 1 to 500 ma. and

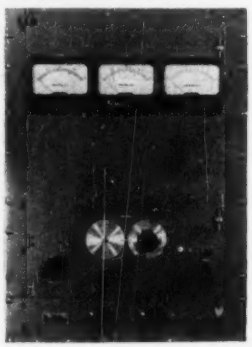


from 1 to 15 amps.; external shunts with leads permit higher ranges. Included in range are 25 to 1,000 mv. and self-contained unit will measure 1 to 500 volts, higher ranges by adding external resistors. As an a-c. rectifier type instrument, range is stated as 1 to 500 volts a.c. self-contained; higher ranges with external resistors. Accuracy is 2 percent of full-scale for d-c. operation; 5 percent when used as an a-c. instrument.—*International Instruments, Inc., 331 East St., New Haven 11, Conn.*

Mention No. 152 when filling out card.

R-f. Phase Monitor

New "Model 109" phase monitor for radio frequencies has an absolute accuracy of 1 degree and resolution and repeatability of 0.1 degree. Phase is



read directly from two dials calibrated in 0.1-degree increments. Instrument continuously and automatically indicates phase difference, hence requires no manipulation on part of operator. Provision is made to indicate antenna current in various towers of a directional array, as well as phase relations.—*Clarke Instrument Corp., 910 King St., Silver Spring, Md.*

Mention No. 153 when filling out card.

Earth-resistivity-type Ground Testers

New "Model 258A" and "Model 257A Vibropots" for earth resistivity measurements are said to "have far greater sensitivity and accuracy than heretofore considered possible in this

TYPE B HIGH PRECISION POTENTIOMETER

This general purpose potentiometer, incorporating a number of notable refinements in potentiometer design, is widely used for precise temperature measurements including thermocouple standardization, for meter calibration, for checking portable potentiometers and for other critical measurements of DC potentials requiring exceptionally high accuracy. Distinctive features include:

1. Three ranges: 0 to 1.6 volts, 0 to 160 millivolts and 0 to 16 millivolts.
2. Three reading dials—effective scale length of approximately 175 feet for each range. Readings easily estimated to within one part in 100,000 of full-scale ranges.
3. Subpanel switch and slidewire construction for protection of contacts from dust and corrosive fumes.
4. Special provisions to minimize parasitic thermal emf's—including automatic compensation of slidewire thermals and gold contacts in galvanometer key.
5. Exceptional convenience in reading and adjustment.
6. Solid and substantial construction for many years of trouble-free service.

PORTABLE PRECISION POTENTIOMETER
A two-dial instrument with built-in standard cell, galvanometer and battery, available in a variety of ranges for laboratory, plant and field applications. Described in Bulletins 270 and 270A.

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Rubicon galvanometers suitable for use with the Type B Potentiometer are described in Bulletin 320.

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NEW BENDIX-PACIFIC TELEMETERING PRESSURE GAGE for 0-400 PSI range

This Pressure Pickup—Assembly No. 421710 (TTP-9A)—provides a new measurement range for Bendix-Pacific AN/DKT-3 Telemetering Systems. It may be used for measurement of differential pressures or for pressures relative to a reference pressure, and may be calibrated from 0 to 5 PSI or any range between 5 and 400 PSI. Differential pressures to a maximum of ± 200 PSI may be measured. ★ Natural frequency is 500 to 2000 cycles per second with the response time dependent upon the length and diameter of the connecting tubing. Acceleration error is negligible. Weight, 0.32 lbs. ★ This new gage complements the Bendix-Pacific series of high pressure gages which range from 0 to 3000 PSI. ★ Bendix-Pacific Telemetering Systems are extremely flexible in design application and maintenance due to the use of unitized, standard dimension telemetering cases and plug-in components. ★ Bendix-Pacific facilities include installation and application engineering, field operation, data reduction and [illegible] evaluation. We are also prepared to supply complete telemetering ground station facilities on request.

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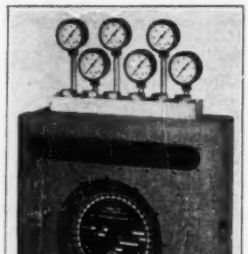

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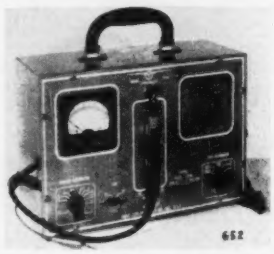
type of instrument; yet are still push-button operated instruments." With an accuracy of 1 percent of the reading at any point on scale and range, "Vibropot" is a d-c. ohmmeter, an a-c. impedance bridge, applicable for earth resistivity measurements by four-point method; also provides laboratory accuracy for testing resistance to earth of man-made grounds. No correction factors are needed, and instrument is independent of auxiliary probe resistance.—*Associated Research, Inc.*, 3758 *W. Belmont Avenue, Chicago* 18, *Illinois.*

Mention No. 154 when filling out card.

Signal Tracer

New "Model 777A Dynatracer" signal tracer has input capacity of only 3 micromicrofarads. Attenuation is 10,000 to 1 by means of a ladder attenuator with vernier control. Sensitivity is 10,000 microvolts for full-scale deflection or 200 microvolts per



division. Frequency range covers approximately 160 Mc. A jack is provided for testing microphones and pickups. Automatic-control switch permits either speaker or indicator to be used alone or together or standby.—*Radio City Products Co.*, 152 *West 25th Street, New York* 1, *N. Y.*

Mention No. 155 when filling out card.

Timing Motor

New self-starting synchronous motors feature high-temperature Glyptol sealing for gear case, hardened-stainless steel rotor shaft, aluminum rotor, and nylon first-reduction gear. Gear-

train housing is dust proof. Rotor is visible through a window. Optional two-way friction clutch has torque of 9 oz.-in., plus or minus 3 oz.-in. Output shafting and speeds according to specifications. For 120 or 240 v. at 60, 50, or 25 cps. Power used, 2.25 watts.—*International Register Co.*, 2616 *W. Washington Blvd., Chicago* 12, *Ill.*

Mention No. 156 when filling out card.

Filterless Dust Collector

New "Model 30N50 Dustkop" develops 3630 cfm. (velocity 10,400 fpm.); measures 28 x 49 in. floor space

x 82 in. over-all height; thus combines high volume with small space requirements. A self-clearing paddle-wheel fan is direct-driven by a 5-hp. continuous-duty motor. Dust-laden air enters unit at 8-in. diameter inlet. Dust, etc., is taken out in cyclone separator and deposited in dust storage compartment which has 12 cu. ft. capacity and forms base of unit. Cleaned air, with any toxic fumes, objectionable smoke, etc., is exhausted to outdoors through outlet at the top of cyclone. Ordinary sheet-metal pipe can be used to complete installation. Additional advantage claimed for this type of equipment is that it is available from stock. —*Aget-Detroit Co., Ann Arbor, Mich.*

Mention No. 157 when filling out card.

Exposure Meter

New "Red Dot" exposure meter utilizes photometric principle: a calibrated lamp illuminates half of a comparison screen, other half is illuminated by light from the scene. When halves are matched (by moving a lever) light value is indicated. From this, proper exposure is found as usual on a circular dial. Instrument is designed for one-hand use, is slightly smaller and thinner than a pack of cigarettes, resembles a photoelectric type exposure meter but its price is almost one-fourth that of photoelectric types. It is calibrated for film speeds from 6 to 400 ASA and has a range of shutter speeds from 2 seconds to 1/800th, apertures from f:1.4 to f:45. Exposure indications are said to be accurate for all normal photographic uses, both indoors and outdoors. Lamp is run at less than normal voltage and, according to announcement, may be expected to hold its calibration "over a long period of time." Two special pen-light batteries (photoflash type) are easily replaced but "do not require frequent change" since drain of lamp is low.— *Lloyd Mfg. Co., Houtzdale, Penna.*

Mention No. 158 when filling out card.

Statistical & Quality-Control Slide Rule

New slide rule, developed in accordance with basic principles of quality control adopted by American Standards Association in Standard Z 1.3 "Controlling Quality During Production," has traditional log-log scale arrangement, specialized quality-control scales, and ordinates and areas for the normal curve. Rule is 12.125 by 2 by 0.156 in. and weighs less than 4 oz. Non-warping light-metal core with op-

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As you want it . . .
when you want it . . .

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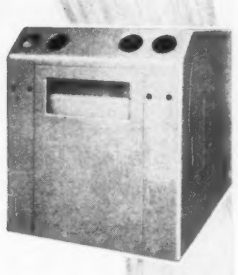

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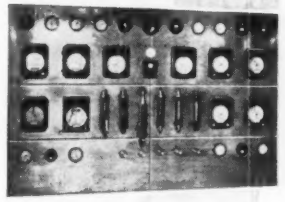

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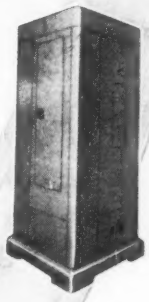

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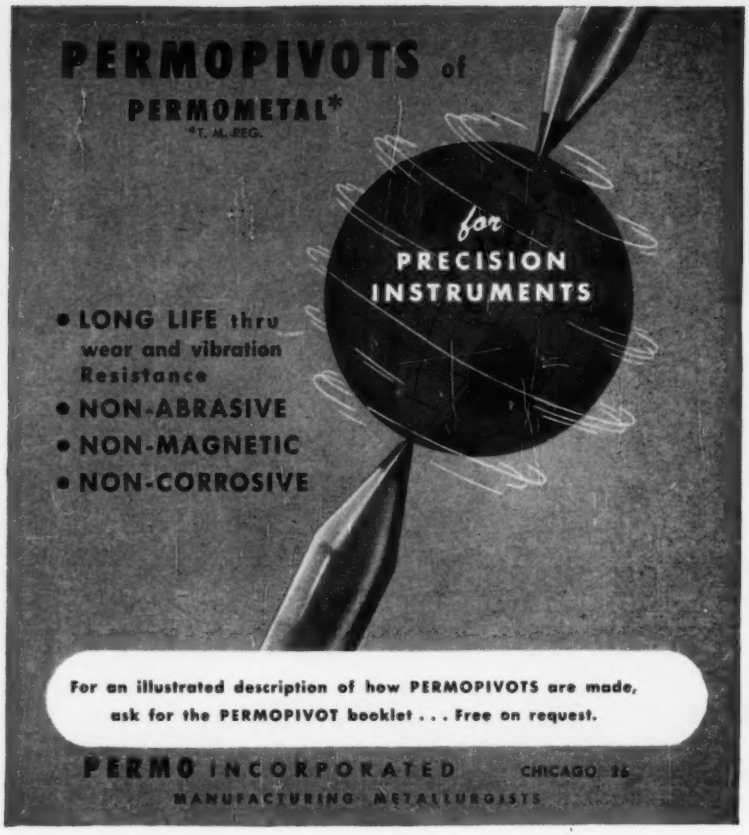

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tical tongues and grooves insure permanent alignment, freedom from distortion, easy operation.—*Pickett & Eckel, Inc., 5 S. Wabash Ave., Chicago 3, Ill.*

Mention No. 159 when filling out card

Rain Gage

New rain gage consists of Tenite plastic tube, a metal frame with graduated scale cut into metal, and a metal cup to funnel rain into tube. Tube will measure up to 6 in. rain without having to be emptied. Readings are

made directly in inches and tenths, and in hundredths by interpolation. All parts are proof against rust or corrosion. A book in which an eleven-year record of rainfall can be kept is included.—*Victor Rain-Gage Co., Airport Branch, Wichita, Kansas.*

Mention No. 160 when filling out card.

Educational Amplistat

New educational amplistat, operating from 115-v., 60-cps line, consists of a saturable reactor and rectifiers mounted in one unit. Assembly is fast-

ened to surface of a textolite panel which has a schematic diagram of component parts molded in its surface. Reactor consists of two main cores each wound with a load winding and four control windings linking both cores.—*Special Products Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 161 when filling out card.

Smoke Density Indicator

New "Type 2A10C" smoke indicator consists of: photoelectric control, light source, and densometer. First two are

MODERN ELECTRONIC ENGINEERING GIVES PRECISE

FINGERTIP SPEED CONTROL

- TACHOMETER PROPORTIONING
- TENSION OR POSITION CONTROL
- MOTOR INTEGRATORS
- BI-DIRECTIONAL
- DYNAMIC BRAKING
- SERVO CONTROL

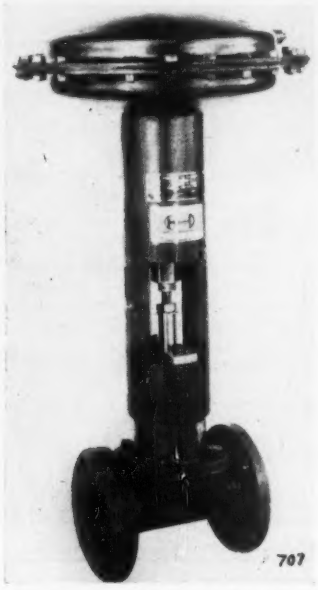
Servo-Tek products co.
4 Godwin Ave. Paterson, N. J.

mounted on opposite sides of flue or breeching. Beam from source projects from an opening in flue to eye of control. Densometer is located on boiler-room instrument panel—*Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.*

Mention No. 162 when filling out card.

Diaphragm-pinch Valves

New "2000 Series" diaphragm-control valves are available for any size up to 12 in. They are designed primarily to handle corrosive fluids or

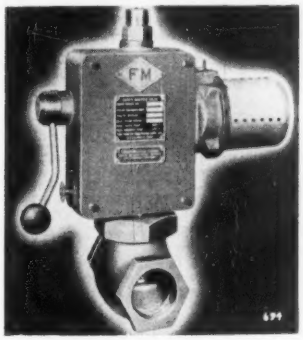


gases or any slurry or fluid carrying solids in suspension. Operating temperature is limited by diaphragm material used, 180 F being considered max. safe figure. Body through 4 in. size is rated at a max. working pressure of 150 psi; 5 and 6 in. for 125 psi; 8 in. at 100 psi; and 10 and 12 in. for 65 psi.—*Hammel-Dahl Co., 243 Richmond St., Providence 3, R. I.*

Mention No. 163 when filling out card.

Shutoff Valve

New "Series 21" safety shutoff valve stops flow of any gas or liquid instantly when current to solenoid is



interrupted. When power is restored, valve is reset manually. It may be tripped closed manually if desired and cannot be wedged or propped open

MAGNA-SIGHT Low-Cost, pipeline FLOW GAUGE

for flow rate indication

A magnetic roller, entirely outside the fluid stream, indicates flow rate on a graduated scale.

FOR—Clear or opaque fluids, slurries

CAPACITIES—3.5 to 250 gpm; 10 to 1 range

PRESSURES—to 500 psig

TEMPERATURES—to 400° F

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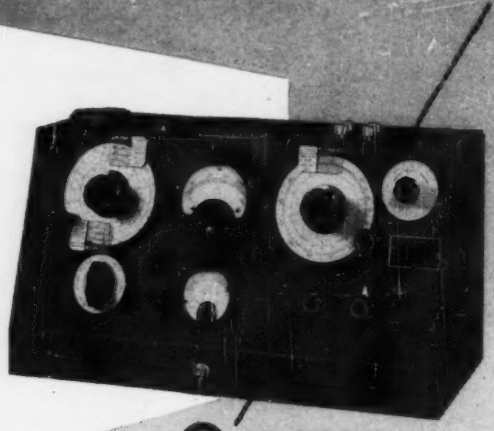

160-A Q METER

The 160-A Q-Meter is unexcelled for laboratory and development applications, having received world wide recognition as the outstanding instrument for measuring Q, inductance, and capacitance at radio frequencies.

Frequency Range: 50 kc. to 75 mc. (8 ranges)
Q Measurement Range: 20 to 250 (20 to 625 with multiplier)
Range of Main Q Capacitor: 30-450 mmf.
Range of Vernier Q Capacitor: +3 mmf., zero, −3 mmf.

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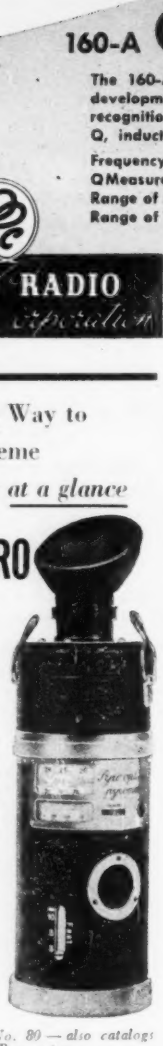
The *Accurate* Way to Measure Extreme Temperatures *at a glance*

The Simplified PYRO Optical Pyrometer



SELF-CONTAINED. No correction charts, no accessories, no up-keep. *Direct-reading.*

ACCURATE. Permits *close* and *rapid* temp. determination — even on *minute spots, fast-moving objects, smallest streams.* ("Special Foundry Type" and "Triple Range" also have RED Correction Scale for determining *true spout* and *pouring* temps. of molten iron, steel in the open.)

LIGHT IN WEIGHT — Only 3 lbs. complete. Handy.

PROVED IN USE—Foundrymen all swear by it.

Stock Ranges 1400°F. to 7500°F.

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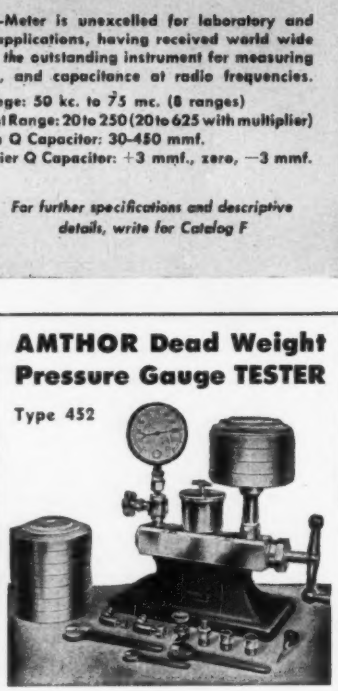
BERGENFIELD 4, NEW JERSEY
In Canada, Sales and Repair Laboratory:
Dominion Flow Meter Company Limited
Toronto and Montreal

AMTHOR Dead Weight Pressure Gauge TESTER

Type 452



Modern design and construction puts this rugged precision instrument in a grade above the ordinary dead-weight testers.

Made in ten ranges, to 5000 lbs. maximum.

We guarantee 1/10 of 1 percent accuracy in each range.

The Type 452 is designed for simplicity and compactness. It incorporates the newest refinements and improvements. Adapters and tools are supplied, as well as either carrying case or protecting cover.

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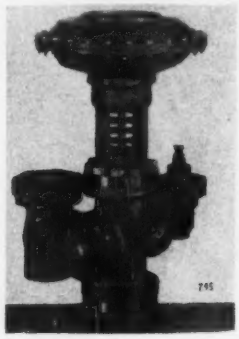
Amthor Testing Instrument Co., Inc.
49a Van Sinderen Ave. Brooklyn, N. Y.

with power off since resetting handle is independent of valve stem. Globe-type soft-seating valve can be had with all-iron body and internals, available in sizes from 0.75 through 6 in.; with solenoids for 110, 220, 440 volts and 60, 50 and 25 cps.—*The North American Mfg. Co., 4455 E. 71st St., Cleveland 5, Ohio.*

Mention No. 164 when filling out card.

Two-pressure Hydraulic Valve

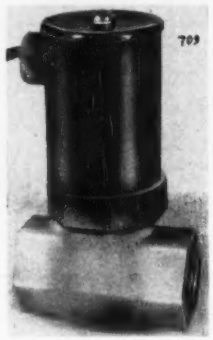
New larger size of "Series 805" valve in 2.5 and 3 in. sizes, for example, is valuable in controlling hydraulic-cylinder operated machinery, which is operated from low pressure to produce long strokes economically followed by application of high pressures from 2000 to 5000 psi. to produce necessary working tonnage. Valve is poppet type throughout, all seats and disks of hardened stainless steel. Seat rings and disks are removable for replacement. Action of three-way valve is balanced, and balancing pistons pass through molded-mechanical packers. Bodies are of heavy-walled bronze castings to 3500 psi. service and for higher pressure of stainless steel.—*Seely Instrument Co., Inc., 377 Fourth St., Niagara Falls, N. Y.*



Mention No. 165 when filling out card.

Solenoid Valves

New line of solenoid valves have internal parts of brass and stainless steel, with packless-type heavy-duty solenoid for pressure from 0 to 300 psi. and temperature 0 to 500 F. Valves are built for water, air, steam, gas and custom requirements.—*A. A. A. Valve Co., Inc., 357 Canal St., New York, N. Y.*



Mention No. 166 when filling out card.

Control Transformers

New control transformers follow closely proposed NEMA standards; are particularly adapted to inductive low-power-factor loads of solenoids, relays, and contactors. Secondary voltage of 60-cycle units remains above 90 percent of rated voltage up to a load current of seven times normal at 20 percent load power factor. Seven sizes from 0.075 to 1.5 kva. are available for 220/440 volts primary to 110 volts secondary at 60 cycles. For 50-cycle operation, six sizes from 0.15 to 1.5 kva.; for 25-cycle operation, three sizes from 0.15 to 0.5 kva.—*Westinghouse Electric Corp.*, 306 *Fourth Ave., Pittsburgh* 30, *Pa.*

Mention No. 167 when filling out card.

Radio-telemetering Receiver

New "Model 167" vhf receiver, designed as terminal equipment in telemetering systems has a frequency range of 210 to 250 Mc. Provision is

made for audio monitoring and for feeding a series of subcarrier discriminators. All transformers and meters are hermetically sealed, and no electrolytic condensers are used. Receiver is treated to resist moisture and fungus growth.—*Clarke Instrument Corp.*, 910 *King St., Silver Spring, Md.*

Mention No. 168 when filling out card.

Copper-oxide Rectifier

New "Model CX14" copper-oxide rectifier features a gold-to-gold internal circuit arrangement made up of vacuum-processed rectifier plates with

gold contacts, specially-treated gold terminals and copper-alloy brackets. Impregnated and sealed to withstand extreme humidity, unit is also fungus resistant. Dimensions are 0.5 by 0.18 by 0.25 in., mounted on a 2-56 by 0.375 screw.—*Bradley Laboratories Inc., New Haven, Conn.*

Mention No. 169 when filling out card.

Electrolytic Capacitors

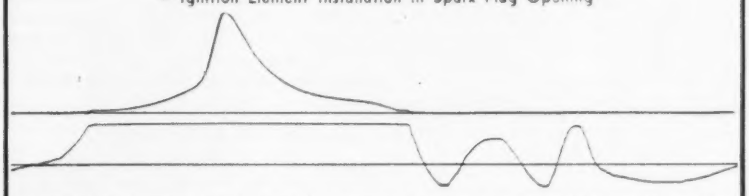
New "Type SRE" electrolytic capacitors in miniature sizes are hermetically sealed in tubular-aluminum cases with wax-impregnated cardboard-insulating jackets. Stud terminals provide max. creepage distances between terminals and can. Despite diminutive size, they comply with RMA tolerance requirements, d-c. leakage-current limits, surge-voltage ratings, operating-

Want the INSIDE STORY?

The Cox Direct Pressure Engine Indicator tells *more of the true* INSIDE STORY of any engine.

Here are REASONS WHY it is an important tool for engine design analysis:

- Pressure Recording and Indicating in All Engines
- Direct Measurement at Instant of Pressure Balance
- Gas Sampling with Same Equipment
- Simultaneous Diagrams from All Cylinders
- Full Scale High and Low Pressure Cards
- Plain Pressure Elements for All Engines
- Ignition Element Installation in Spark Plug Opening



Unretouched (quarter-size) high and low pressure diagrams and atmospheric line taken with only one element in the combustion chamber. Manifold and exhaust pressure diagrams taken at the same time are not shown. Above card is typical of the unique flexibility and accuracy of the equipment for studying cylinder and manifold pressures and gas samples to determine combustion analysis, mixture ratio, stratification, turbulence, scavenging, peak pressure, pressure rise, mean effective pressure, valve pressure drop, exhaust back pressure and pulsation.

For the **true** INSIDE STORY, use a Cox Direct Pressure Indicator to determine conditions inside the cylinders and manifold . . . Where performance starts.

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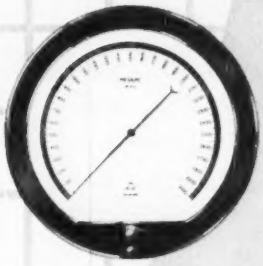
one-second zero setting with revolving dial and external knob



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Zero adjustment in Heise Bourdon pressure gauges is simply a matter of turning an external knob with the fingers. No tools are needed. Nothing is removed. The knob rotates the dial until zero and pointer coincide. Direct readings of absolute pressure can be made by setting the dial to agree with barometric pressure.

Three sizes: 8½ in., 12 in., and 16 in., in ranges from 0-15 to 0-10,000 psi. Prices from $151.60 to $211.20. Write for catalog.

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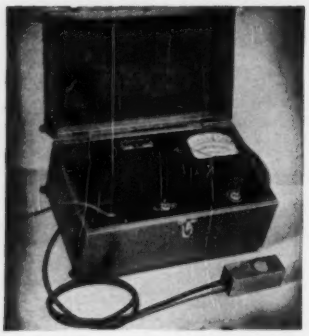
Newtown, Connecticut

S·S·White MOLDED RESISTORS

The All-Weather Resistors



ARE USED IN THIS ULTRA SENSITIVE ELECTRONIC PHOTOMETER

In this instrument—designed for measurement of very low light values—S.S.White Resistors serve as the grid resistance in the all-important high-gain D.C. amplifier circuit. The manufacturer, Photovolt Corp., New York, N. Y., reports that the resistors "work very satisfactorily"—which checks with the experience of the many other electronic equipment manufacturers who use S.S.White resistors.

S.S.WHITE RESISTORS

are of particular interest to all who need resistors with inherent *low noise level* and *good stability* in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS
STANDARD RANGE
1000 OHMS to 9 MEGOHMS

WRITE FOR BULLETIN 4906

It gives essential data about S.S.White Resistors, including construction, characteristics, dimensions, etc. Copy with price list on request.

Photo courtesy of Photovolt Corp., New York, N.Y.

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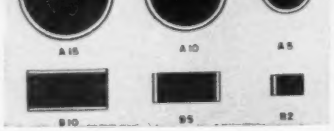
SELENIUM PHOTOELECTRIC CELLS

Self-generating — No external power source required.

Sensitivity — Up to 600 microamps per lumen.

Stable Characteristics - Long Life



Cell	Size	Output-μa*
A15	2" diam.	800
A10	1¾" diam.	550
A5	1⅛ diam.	250
B10	1-11/16"x⅞"	340
B5	1-7/16"x41/64"	220
B2	23/32"x7/16"	75

*At 100 ft.—Candles & ext. Resistance of 100-ohms

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MODEL 700
DECIMAL COUNTING UNIT

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temperature ranges, etc. Life is comparable with that of larger electrolytics.—*Aerovox Corp., New Bedford, Mass.*

Mention No. 170 when filling out card.

D-c.-drive Choppers

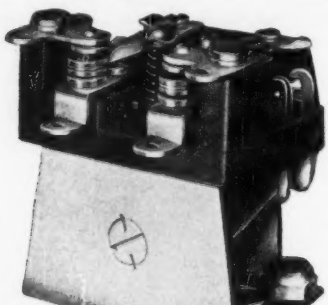
New self-excited choppers are a combination of s-p. d-t. and s-p. s-t. choppers mounted together in one hermetically-sealed high-permeability container on an 8-pin octal base. Coil is for 6 or 26 volts at 1.5 watts. Contacts nominally handle 10 volts at 0.001 amp,

d-c., or higher values for intermittent duty. Vibration frequency is 120 per sec. Choppers are useful as modulators, rectifiers, demodulators, or square-wave generators for low-level signals from thermocouples, strain gages, or servomechanism error voltages.—*Stevens-Arnold Inc., 22 Elkins St., S. Boston 27, Mass.*

Mention No. 171 when filling out card.

Relays

New line of electrical relays, headed by compact general-purpose "BO" model, will be available from retail outlets throughout country. Relays



have previously been used as components by manufacturers of electronic and electrical equipment.—*Allied Control Co., Inc., 2 East End Ave., New York 21, N. Y.*

Mention No. 172 when filling out card.

Multiplier Phototube

New "5819" multiplier photo-electric tube is specially designed for use with scintillation counters. With a "head-on" cathode measuring 1.5 in. dia., a sen-

sitive area several times that of previous models is attained. The resolving time of less than one-hundred millionth sec. is considerably faster than that of Geiger tubes. Effective spectral sensitivity ranges from near ultra-violet to orange.—*Tube Dep't, Radio Corp. of America, Camden, N. J.*

Mention No. 173 when filling out card.

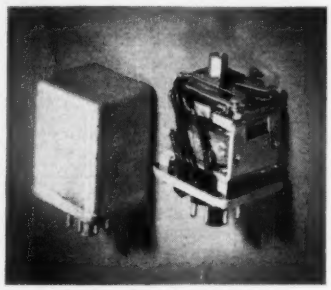
Multiplier Phototube

New characteristics of maker's "1P21" multiplier phototube reduce equivalent noise input to 5 x 10^{-18} lumen, a sixfold improvement in performance. Tube is particularly suited to use in spectrometers, astrotelescopes, scintillation counters and other equipment where collimated-light beams are employed.—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*

Mention No. 174 when filling out card.

Miniature Relay

New "Frame 181" relay structure offers maximum resistance to mechanical stress. Balanced armature minimizes false contact operation under shock and vibration. Relays have ap-



proximately 50 percent more coil volume than existing types of comparable size, and magnetic structure has two working air gaps. Any contact arrangement up to 4-pole d-t. can be furnished as a standard open-type relay or with plug-in base and removable or hermetically sealed metal cover.—*Struthers-Dunn, Inc.*, 150 *N. 13th St., Philadelphia 7, Penna.*

Mention No. 175 when filling out card.

A-c. Electrolytic Capacitors

New "Type 11A" electrolytic capacitors for 115-volt continuous-duty a-c. service may be used in applications where starting-voltage surges across capacitors may exceed rated voltages by as much as 50 percent for a maximum of two seconds. Another important use is where a voltage drop is required without power dissipation.—*Sprague Electric Co., North Adams, Mass.*

Mention No. 176 when filling out card.

Refractive-index Recorder

CORRECTION

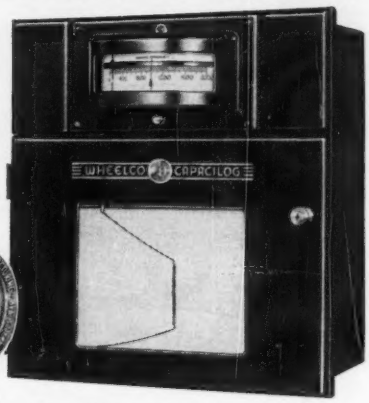
Item No. 1208, page 1109 of our December issue:—A line of type was dropped out at the end, which should read as follows: "34 in. high, 24 in. wide.—*Precision Scientific Co.*, 3737 *W. Cortland St., Chicago 47, Ill.*"

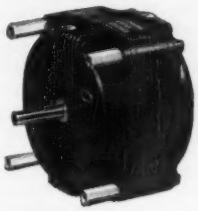
AWARD-WINNING **TEMPERATURE RECORDER**

uses a

BODINE MOTOR

The new Wheelco Deflection-Type Temperature Recorder was recently judged one of the five outstanding designs of the year in the Eleventh Annual Product Design Competition conducted by *Electrical Manufacturing Magazine*.





A Bodine Type K motor positions the follow-up arm and pen. This motor was selected because of its precise, reliable operation and rugged construction.

The Type K motor is especially designed for use on instruments and controls. Write for complete information. Bodine Electric Company, 2244 W. Ohio Street, Chicago 12, Illinois.

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4. Many attachments available to increase versatility, such as extension arm, rapid self-centering vise, extension post for pantograph and copy carrier, hand engraving spindle and many more.
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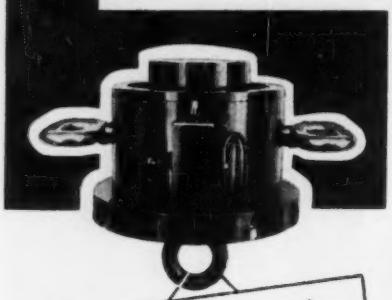
Force Measuring systems



for use in applications such as dynamometers, industrial weighing, strength of structures, jet engine thrust, and countless other force-measuring problems. Illustrated is the famous Emery Hydraulic Cell, basic unit of Emery hydraulic testing and force-measuring systems.

All components are simply constructed, but rugged; they are compact in size, extremely sensitive and accurate. Easy to mount and use. Send for complete literature and prices; also our engineers will be pleased to discuss your force-measurement problems and make recommendations.

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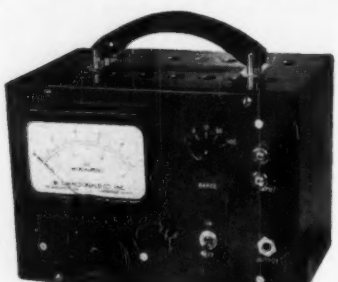
Wanted: Instrument Personnel

Draftsman — Designers — Project Engineers. Experience: Aircraft or Industrial Pressure Instruments, Gyroscopes, Flight Test Instrumentation, and Controlling Switches. California location. Answer full details. Box 173, Instruments Publishing Co., Pittsburgh 12, Penna.

MACDONALD ELECTRONIC MICROAMMETER



THIS instrument is designed to replace high-sensitivity galvanometers in many applications. Due to its ruggedness, freedom from burnout, and relative insensitivity to shock, it is an ideal instrument for use in balancing resistance bridges, measuring crystal rectifier output, photo-cell, strain-gage, thermocouple, and lead-sulphide cell currents, etc. The instrument may also be used as a DC pre-amplifier for recorders. When used in this manner, current amplification of 1,000 is available.

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1 microampere full scale
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Permissible overload – ¼ ampere
Accuracy – ±3% full scale
Time constant – about 6 seconds
Power supply – 110 – 125 V, 60 C.P.S.
Dimensions – 7" x 8" x 9½".

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25th YEAR — Milsco MILWAUKEE

JOURNAL of the Instrument Society of America

I.S.A. National Office, 921 Ridge Ave., Pittsburgh 12, Penna.

Vol. 6 JANUARY 1950 No. 1

An Open Letter to Members

Dear ISA Member:

The 1949 operations of your Society have lacked spectacular features, nevertheless we believe that progress has been made.

The addition of 316 new members to our rolls since April 1949 is proof of the growth of instrumentation in science and industry and is strong evidence that ISA membership is considered a virtual necessity by instrument men.

Total membership now is 4,224. The number of Sections has increased from 45 to 49 since that date; Wilmington, Delaware being the latest to receive a charter.

The 42 papers presented at the St. Louis Conference in September set a new record for ISA meetings. The St. Louis Exhibit also set a record for products exhibited.

The 1950 meeting is planned for the Memorial Auditorium, Buffalo, September 18th to 22nd. The location of this meeting will permit the attendance of many members who have heretofore not attended a meeting.

The social function at St. Louis, the River Excursion on the Steamer Admiral, also set a record for attendance and good fellowship.

The list of sections and their membership is as follows: Akron 44, Albuquerque 43, Aruba 63, Atlanta 17, Baltimore 78, Boston 95, California 166, Central Illinois 34, Central Indiana 82, Charleston 83, Chicago 323, China Lake 89, Cincinnati 69, Cleveland 135, Columbus 28, Cumberland 15, Detroit 72, Eastern New York 105, Gulf Coast 45, Houston 120, Kansas City 58, Louisville 40, Montreal 73, New Jersey 232, New Orleans 6, New York 221, Niagara Frontier 91, North Texas 44, Northern California 91, Northern Indiana 24, Oak Ridge 67, Ontario 44, Philadelphia 360, Pittsburgh 224, Presque Isle 23, Richland 102, Rochester 70, Sarnia 82, South Bend 12, South Michigan 33, South Texas 45, St. Louis 141, Tennessee 47, Tulsa 92, Twin Cities 45, Washington 129, Wayne County 35, Wilmington 33, Members at large 34.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio.
Fourth Tuesday, Meeting at 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
L. J. Paddison, 911 Parkland Circle, Albuquerque, N. M.

ARUBA
K. H. Walker, P. O. Box 389, c/o Lago Oil & Tranpsort Co., Ltd., Aruba, N.W.I.
First Tuesday, Meeting at 7:15 P. M.

ATLANTA
H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P. M.

BALTIMORE
George B. Greer, 631 E. 36th St., Baltimore 18, Md.
Second Friday.

BATON ROUGE
Jack L. Pillow, 801 Lake Park Drive, Baton Rouge, La.

BOSTON
C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.
Last Wednesday, Dinner at 6:30 P. M.., Meeting at 7:00 P.M., Patten's Restaurant.

CALIFORNIA
D. D. Taylor, 1955 Mendocino Lane, Altedena, Calif.
First Tuesday, Dinner at 6:30 P. M. Meeting at 8:00 P. M.

CENTRAL ILLINOIS
H. F. Lange, 2101 W. Glen Avenue, Peoria 5, Ill.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
H. F. Coffey, 4029 N. Temple Ave., Indianapolis, Ind.
First Tuesday, Meeting at 7:30 P. M.

CHARLESTON
S. E. Mitchell, 312 24th St., Dunbar, W. Va.
First Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Kanawha Hotel.
February 6, "What Makes an Instrument a Good Instrument?", R. E. Clarridge, Taylor Instrument Cos.

CHICAGO
Floyd E. Ertaman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill.
Third Tuesday, Dinner at 6:45 P. M., Meeting at 8:00 P.M., W.S.E. Auditorium.
January 17, Western Society of Engineers (84 E. Randolph St.). "Automatic Control and the High Speed Analog," G. A. Philbrick, G. A. Philbrick Researches, Inc.
February 7, "Flow Meter Installation Troubles," J. B. McMahon and W. L. Eckdahl.

CHINA LAKE
A. G. DeBell, U. S. Naval Ordnance Test Sta., China Lake, Calif.

CINCINNATI
Edward H. Muhleisen, 320 Durrell Ave., Cincinnati 15, Ohio
First Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

CLEVELAND
R. M. Woodside, 332 Oakmoor Rd., Bay Village, Ohio
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society.

COLUMBUS
Orval Linebrink, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio
Third Thursday, Battelle Auditorium.

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md.
Tuesday after Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Algonquin Hotel.

DETROIT
Seymour Sterling, 13331 Linwood, Detroit, Mich.
Second Wednesday, Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
W. R. McKegg, c/o General Engineering & Consulting Lab., General Electric Company, Schenectady, N. Y.
First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

GULF COAST
W. N. Sloan, 2558 Tyrrell Parkway, Port Arthur, Texas.
Third Tuesday, Meeting at 7:30 P.M., Lamar College.

HOUSTON
E. E. Kleir, c/o The Foxboro Co., 2518 S. Blvd., Houston 6, Texas
Last Monday, Meeting at 8:00 P.M., Engineers Club.
January 30, "Improvised Instrumentation," R. L. Nichols, Magnolia Petroleum Co.
February 27, "The Manufacture of Starch for Food and Industry," T. H. Pierson, Corn Products Refining Co.
March 27, Banquet and Installation of New Officers.

KANSAS CITY
Lewell F. Spies, c/o J. F. Pritchard & Co., 908 Grand Ave., Kansas City, Mo.
First Tuesday, Meeting at 7:30 P. M.
February 7, "pH Control and Its Applications," Dr. A. O. Beckman.
March 7, "Refinery or Chemical Process Control," Hart Fisher, Monsanto Chemical Co.

LOUISVILLE
H. C. Scherffius, 980 Palatka Rd., Louisville 8, Ky.
Fourth Tuesday, Meeting at 8:00 P.M.

MONTREAL
L. J. Mizuhara, Monsanto (Canada) Ltd., 425 St. Patrick St., Ville LaSalle, Quebec, Canada
Last Monday, Meeting at 8:00 P.M.

NEW JERSEY
W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House.

NEW ORLEANS
W. H. Haney, 2927 Music Avenue, New Orleans, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
Norman J. Cherry, P. O. Box 608, Merrick, L. I., N. Y.
Last Monday, Meeting at 7:30 P.M., Statler Hotel.
January 27-28, January Conference at Statler Hotel. "Temperature Measurements", Theory, Practical Instrument Application and Maintenance Problems. Banquet on Friday Evening.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 9, N. Y.
Fourth Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Institute of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9, Texas

NORTHERN CALIFORNIA
M. A. Dimmick, 5607 Alta Punta, El Cerrito, Calif.
Third Monday, Meeting at 7:30 P.M.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill.
Third Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Gary Y.M.C.A.
February 7, Joint Meeting with The Chicago Section.

OAK RIDGE
John H. Clark, 138 Clayton Hall, Oakridge, Tenn.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada
Third Thursday, Dinner at 6:45 P. M. Meeting at 8:15 P. M.

PHILADELPHIA
C. W. Wood, 6908 Market St., Upper Darby, Pa.
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.
January 18, "New and Interesting Developments in Television."

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa.
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel.
January 23, "Stump the Experts." A Main-

Continued on page 76

Dynamic Accuracy In Temperature Measurement*

By J. G. ZIEGLER and N. B. NICHOLS†

THE dynamic performance of a temperature measuring element is concerned with its behavior under changing or *dynamic* conditions as contrasted with the static performance under constant conditions. The usual accuracy specifications are limited to the static accuracy since it is relatively easy to define the static test conditions and to reproduce these test conditions whenever necessary. The dynamic accuracy is often partially described by giving the speed of response for some given set of dynamic test conditions, but more generally, little attention is paid these characteristics of the measuring element. An instrument accurate to a fraction of a degree under static conditions can easily be in error by a great many degrees when the temperature is changing.

The inability of thermometric elements to accurately follow changing temperature not only produces errors in measurement; it often has a profound effect on the results obtainable when the temperature is automatically controlled. In certain control applications, elimination of measurement "lag" would remove such a large proportion of the effective control circuit lag that temperature deviations could be practically eliminated. An example of such a process is shown in Fig. 1; a steam heated surface raising an air stream to a controlled temperature. A sudden change in the temperature or flow of incoming air would cause a temperature deviation and recovery as shown by the dotted line. The actual chart record would not be as alarming due to the presence of measurement lag as shown by the solid line, but the dotted record of air temperature would be shown by a measuring element with perfect dynamic characteristics installed beside the imperfect element of the controller. If the controller were actuated by the perfect measuring element and properly adjusted for the easier task which it would then have, a similar change in load would be corrected very quickly and with almost no temperature deviation.

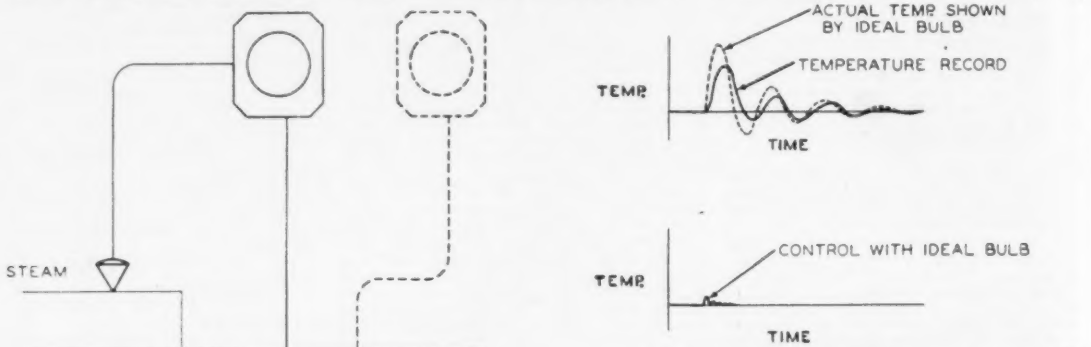

Fig. 1. Air heater system and response curves. This process is an example of a control system where measurement "lag" elimination achieves good control.

All practical temperature measuring elements are imperfect dynamically simply because some heat is required to change their temperature and there is only a finite surface area through which the heat can flow. Consider the temperature measuring element of Fig. 2 having two important characteristics, a heat capacity of 0.004 BTU per °F and a surface area of 0.024 square feet. If this element be immersed in a fluid flowing at such a velocity past the surface that the coefficient of heat transfer

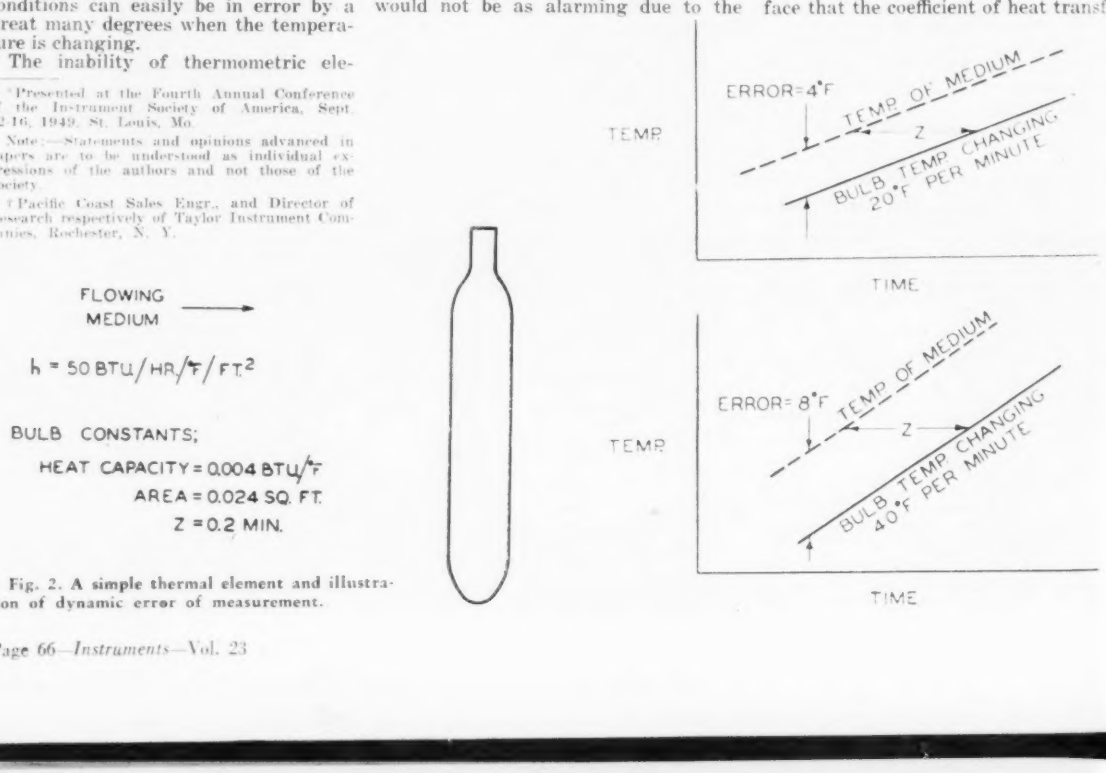

Fig. 2. A simple thermal element and illustration of dynamic error of measurement.

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

Note:—Statements and opinions advanced in papers are to be understood as individual expressions of the authors and not those of the Society.

†Pacific Coast Sales Engr., and Director of Research respectively of Taylor Instrument Companies, Rochester, N. Y.

is 50 BTU/hr./°F./ft.² the dynamic characteristics of the system may be established. If the temperature reading is increasing at the rate of 20° per minute, as shown in Fig. 2, a certain amount of heat must be flowing into the element.

$$q = (20)(60)(0.004) = 4.8 \text{ BTU/hr.}$$

All of this heat must flow through the fluid film surrounding the bulb and, since the rate of heat flow is constant for a given rate of temperature change, the temperature drop over the film may be calculated from the conventional steady state heat transfer equation.

$$q = h\,A\,\Delta T$$

$$\Delta T = \frac{q}{(h)(A)} = \frac{4.8}{(50)(0.024)} = 4°\text{F.}$$

Thus, in order to keep the element temperature rising at a rate of 20° per minute, the medium temperature must remain 4°F higher. Thus in this example, the dynamic error of measurement is 4°F. Under similar conditions, since the rate of heat flow is proportional to the temperature difference, an 8°F. drop would be required to cause the element to change twice as fast or 40° per minute. The dynamic error then varies with the rate of temperature change of a thermometric element so it is generally more convenient to express the dynamic characteristics of a given element in a given medium as a ratio of the dynamic error to the rate of temperature change. This ratio Z has the dimensions of time and is called "Bulb Lag" which in the example of Fig. 2 is equal to:

$$Z = \frac{\text{(dynamic error)}}{\text{(rate of temp. chg.)}} = \frac{4}{20} = \frac{8}{40} = 0.2 \text{ min.}$$

The meaning of this quantity is shown on Fig. 2 and is the time by which the thermometer reading lags the true temperature when both are changing at constant rate. A better interpretation is that the dynamic error would be reduced to zero in a time equal to Z (provided the bulb temperature kept changing at the same rate). This is shown on Fig. 3 for two cases. In the first, the bulb is subjected to a sudden increase in temperature and responds on a curve of constantly decreasing slope. But at any instant, it is changing at a rate proportional to the remaining temperature difference so it would reduce the error to zero in the same length of time if it continued at its instantaneous slope. In the second case, the true temperature (potential) is assumed to change from one value to another at a constant rate. Note that the bulb reading approaches a limiting maximum slope equal to that of the potential. At every instant, the reading is changing at a rate that would reduce the error to zero in a time equal to Z.

In terms of the bulb heat capacity C and its area A and the coefficient of heat transfer "h" the bulb lag "Z" is equal to:

$$Z = \frac{C}{(A)(h)}$$

This equation indicates some of the possibilities for reducing bulb lag. Any increase in the coefficient of heat transfer effects a corresponding decrease in bulb lag. This indicates that bulbs should always be located at a point where the velocity of fluid is high since "h" increases approximately as the square root of velocity. A little care in this respect can have a very marked effect on bulb lag and on temperature control obtainable. By the same token, the coefficient of heat transfer is much greater in agitated liquids than in gases or even vapors at low velocity, so if a choice exists, the better medium should surround the bulb. Examples of this exist in fractionating columns, evaporators, etc. The vapor leaving a boiling liquid will be at the temperature of the liquid so it should be much better to install a bulb in the liquid on a column plate than in the vapor space between plates. In the case of an evaporator in which the liquid has a boiling point rise, the vapor will be superheated and consequently a gas film would surround a bulb located in the vapor space. The bulb should be located in the liquid. Even in saturated vapors, bulb location should be checked carefully to be sure that it is not in a pocket where fixed gases can collect.

Another possibility of reducing bulb lag is to change the bulb itself, so as to reduce its heat capacity or increase the area, that is, reduce the value of C/A. The most common method is to reduce the bulb diameter, going to the so-called "capillary bulbs" in tube system instruments or to bare thermocouples or resistance thermometers made of the smallest diameter wire which will stand the mechanical strain or the erosive and corrosive conditions encountered in the application. Occasionally finned bulbs are used, although the improvement that can be effected is limited. In general, for bare bulbs or thermocouples, without a protecting well, the internal resistance of the bulb is negligible compared to the fluid film resistance on the outside and the bulb can be considered homogeneous. Actually, there is a slight resistance to heat flow through the metal of the bulb which adds a fraction of a second to the lag caused by the fluid film, but the latter is much larger, varying from a second or two up to several minutes. This is not the case for thermometric elements installed in protective wells unless exceptionally good thermal contact exists between the sensitive element and the well since an air space of a few ten thousandths of an inch between the two can add many seconds to the overall bulb lag. In addition, a more complex "two capacity" lag results which will be considered later after another method of reducing the lag of bare bulbs is explored.

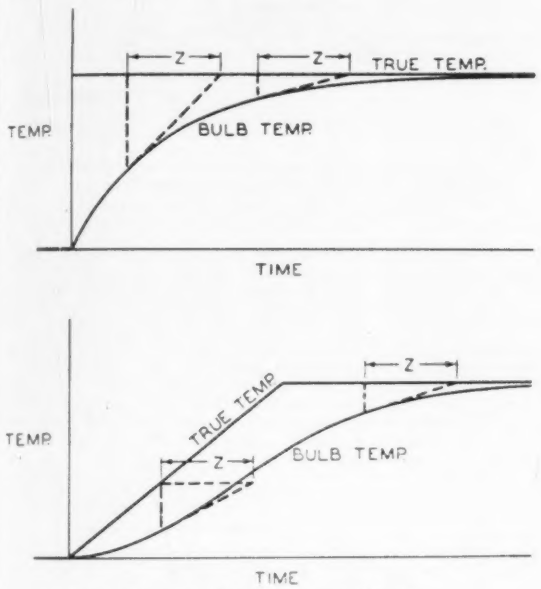

Fig. 3. Response of simple thermal element.

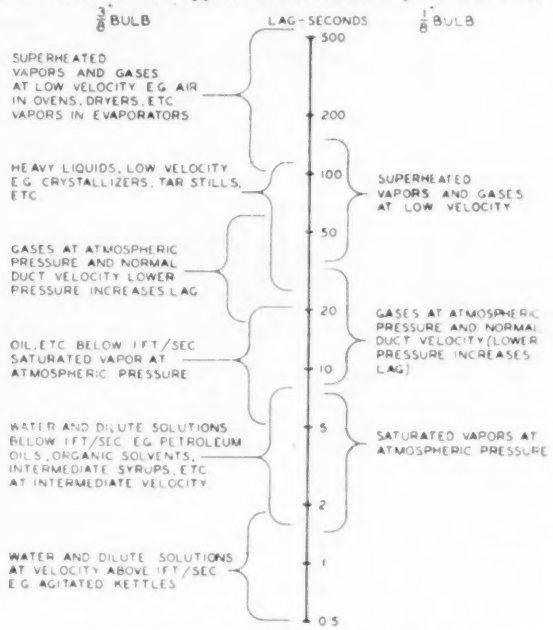
3/8" BULB
LAG - SECONDS
1/8" BULB
500
200
100
50
20
10
5
2
1
0.5
SUPERHEATED VAPORS AND GASES AT LOW VELOCITY E.G. AIR IN OVENS, DRYERS, ETC VAPORS IN EVAPORATORS
HEAVY LIQUIDS, LOW VELOCITY E.G. CRYSTALLIZERS, TAR STILLS, ETC
SUPERHEATED VAPORS AND GASES AT LOW VELOCITY
GASES AT ATMOSPHERIC PRESSURE AND NORMAL DUCT VELOCITY LOWER PRESSURE INCREASES LAG
GASES AT ATMOSPHERIC PRESSURE AND NORMAL DUCT VELOCITY (LOWER PRESSURE INCREASES LAG)
OIL, ETC BELOW 1 FT/SEC SATURATED VAPOR AT ATMOSPHERIC PRESSURE
WATER AND DILUTE SOLUTIONS BELOW 1 FT/SEC E.G. PETROLEUM OILS, ORGANIC SOLVENTS, INTERMEDIATE SYRUPS, ETC AT INTERMEDIATE VELOCITY
SATURATED VAPORS AT ATMOSPHERIC PRESSURE
WATER AND DILUTE SOLUTIONS AT VELOCITY ABOVE 1 FT/SEC E.G. AGITATED KETTLES

Fig. 4. Graphic presentation of normal thermal lags for common industrial process fluids.

Derivative Compensation for Thermal Lag

Even with good installation practice and the use of bulbs with low C/A values, the lag is often larger than can

be tolerated; measurement of transient changes cannot be made with accuracy or control results are miserable. In Fig. 4, approximate values of normal bulb lags are given for a variety of conditions for bulbs ⅜" and ¼" in diameter. These values are not limited to tube system type thermal elements; they apply equally well to a bare thermocouple ⅛" in diameter or to a thermocouple *welded* into a ⅜" tube since the C/A values will be essentially the same. The values would not apply to resistance thermometers in protective tubes because high thermal conductivity can-

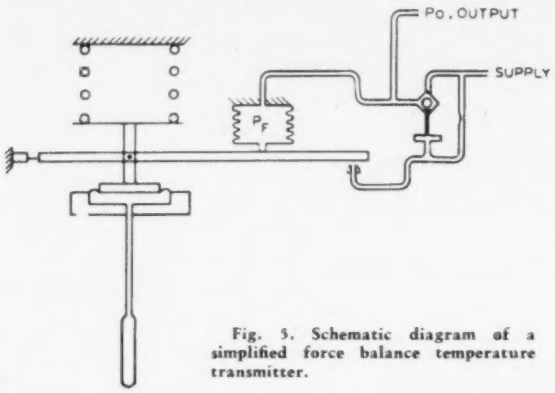

Fig. 5. Schematic diagram of a simplified force balance temperature transmitter.

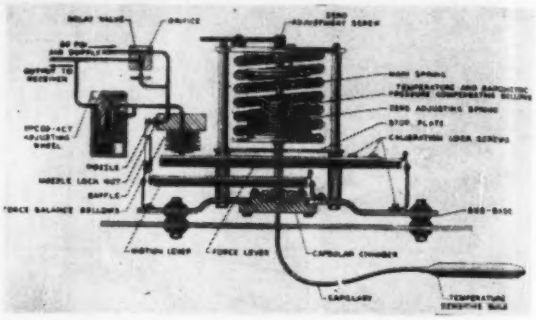

Fig 6. Schematic diagram of a temperature transmitter with dynamic conpensation for measurement "lag."

not be obtained without electrical contact.

Reference to the table shows that bulb lags are not inconsiderable in most cases. The possibility of using small diameter bulbs is generally limited to installation in non-corrosive and non-erosive gases and vapors; even ⅜" diameter bulbs are often too frail to stand the mechanical stresses encountered in flowing streams of viscous liquids. Any increase in wall thickness or contact with supporting members increases the lag by increasing the capacity or impeding free circulation about the bulb. In view of the rather obvious requirements for faster speed of response it seems desirable to point out another way of improving the dynamic accuracy of thermal systems.

As in most compensation problems, the method is quite simple. A quantity proportional to the error is measured or sensed and a correction is applied to the reading so that the final result is the sum of the uncorrected reading and the correction. In this case, the error is the temperature difference between the sensitive element and the temperature of the medium and is equal to:

$$\Delta T = \frac{(dT)}{(d\theta)} \bullet \frac{(C)}{(A)} \bullet \frac{1}{h} = \frac{(dT)}{(d\theta)} \bullet Z$$

Since the error is proportional to the rate of change of bulb temperature, $dT/d\theta$, one merely needs to measure this rate of change, multiply by the appropriate bulb lag and add this correction to the bulb temperature to obtain the corrected or true temperature. The pneumatic transmitter offers an easy solution to this problem. Consider the simplified circuit of a force balance pneumatic transmitter as shown in Fig. 5. A gas filled tube system has its bulb immersed in the process medium. The force resulting from the gas pressure on the diaphragm is balanced by the biasing spring and the force from the balancing bellows. An increase in bulb temperature for example will move the baffle away from the nozzle, decreasing the nozzle back pressure and increasing the relay valve output pressure. This increase in output pressure, flowing into the balancing bellows, applies an opposing force to the diaphragm of sufficient magnitude to substantially prevent movement of the diaphragm and baffle. The change in balancing bellows pressure is then directly proportional to the change in the bulb pressure which is in turn, proportional to its temperature. By suitable calibration, a balancing bellows pressure change of say, 3 to 15 psi can be made to correspond to the desired temperature span of the transmitter. The output pressure is then transmitted to a suitable pressure receiver also having a pressure span of 3 to 15 psi. Ambient temperature and barometric pressure compensation would, of course, be required in any complete instrument, although they are not shown.

Returning to the derivative compensation for thermal lag or "dynamic compensation," we note that the rate of pressure rise in the balancing bellows is directly proportional to the rate of temperature rise of the gas-filled bulb. Increasing pressure in the balancing bellows will require the flow of air into the bellows. In fact, the rate of flow of air into the bellows is directly proportional to the rate of pressure rise in it. Introducing a capillary or needle valve restriction in the line to the balancing bellows will result in a pressure drop which is proportional to the air flow and thus proportional to the rate of temperature rise of the bulb. The output pressure of the relay valve will thus be equal to the balancing bellows pressure plus this pressure drop. Suitable adjustment of the restriction allows selection of the appropriate lag correction factor to neutralize the dynamic error. The adjustment dial on the restriction can, in fact, be calibrated directly in terms of the time lead (or dynamic compensation factor) introduced by it.

Design and Operation of Temperature Transmitter with Dynamic Compensation

The principal involved in this instrument is quite simple. Fig. 6 shows a schematic diagram of a temperature transmitter utilizing this principal.[1] The dynamic compensation or "Speedact" response is obtained by means of a needle valve in the line between the

[1] Taylor "Transaire" Temperature Transmitter with "Speedact."

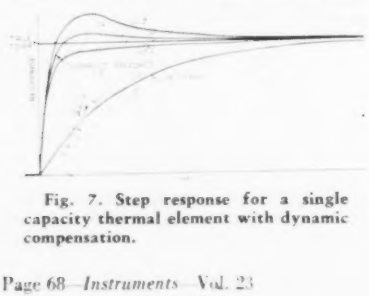

Fig. 7. Step response for a single capacity thermal element with dynamic compensation.

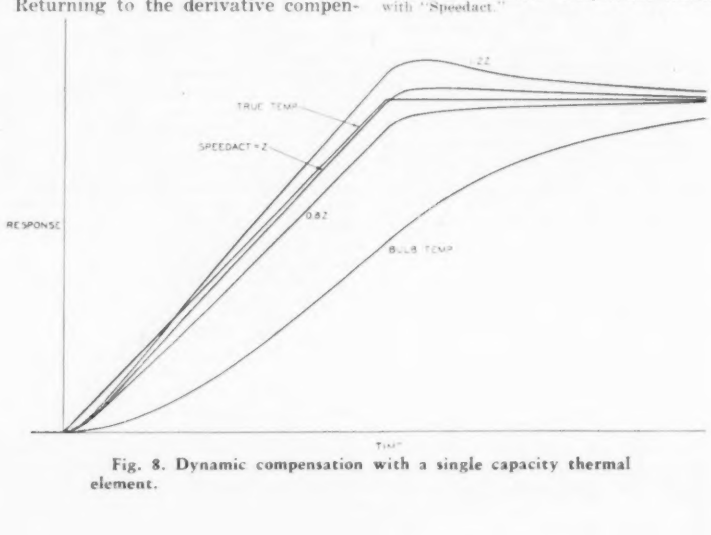

Fig. 8. Dynamic compensation with a single capacity thermal element.

relay output (which goes to the receiver) and the balancing bellows. The needle valve unit incorporates a free bellows with one side connected to output and the other to the balancing bellows. This construction results in stable pneumatic operation as the needle valve is adjusted from wide open to the closed off position. The lead time (lag compensation or "Speedact" time) dial is directly calibrated from 2 to 200 sec. The performance which can be obtained when the thermal system can be regarded as a single capacity thermal element is shown in Figs. 7 and 8. The time scale is expressed in terms of the bulb time constant (Z), as previously described.

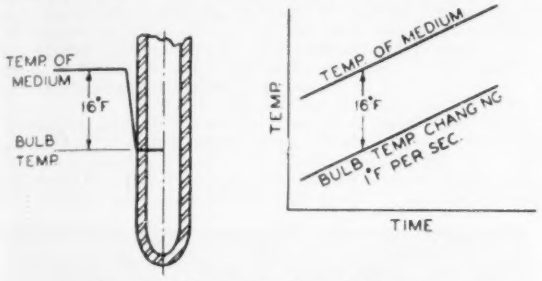

Fig. 9. Single capacity thermal element.

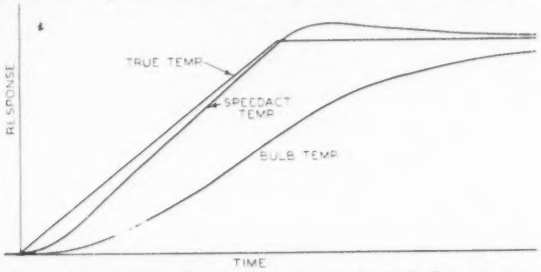

Fig. 11. Response of a single capacity thermal element to a gradual change.

Such a transmitter makes possible temperature measurement not previously obtainable since it produces a much faster response to temperature changes in mediums normally giving excessive measuring lag, such as oils, viscous liquids, vapors and gases. Used for measuring air temperature and humidity in conditioned spaces it shows variations that were previously unsuspected because they were not observable on conventional measuring devices. In the laboratory, it has shown the true course of temperature during a few second test for thermal death rate of bacteria. When the bulb is placed in an air stream at a higher temperature, the reading quickly moves to the true temperature, (Fig. 7), although many seconds later the bulb temperature is still well below that of the air.

Adjustment of the instrument for the particular application lag can be made in a number of ways. Generally, the lag can be estimated from tables with sufficient accuracy. Figs. 7 and 8 show the effect of insufficient or excessive setting of the "Speedact" response. Note that insufficient "Speedact" gives something less than complete compensation for bulb lag and that excessive settings show greater deviations than actually occur although in either case, the readings are nearer the true value than those which would be indicated by the bulb.

Precise "Speedact" setting can be easily made if known changes in temperature can be effected. For example, if the bulb can be removed from its position in the process where the temperature is known and heated or cooled to a different temperature and then returned to the process, the "Speedact" adjustment may be quickly turned until the receiving instrument indicates the true temperature. If the exact medium temperature is not known, the same test can be made and the adjustment turned until the receiver reading or the output of the transmitter is stationary; if the bulb temperature is rising and an excessive setting is made, the reading will decrease and vice versa.

Two Capacity Thermal Element

As mentioned earlier, the response of a thermal element installed in a protective well is more complex than that of a simple bare bulb. If infinitely good thermal contact existed between the bulb and its covering, the only increase in lag would be that caused by the increase in the heat capacity per unit outside area. This can be achieved if the covering is plated on the bulb, or if a sheath is soldered to the bulb. In the usual arrangement in which the bulb or thermocouple is made removable from the well, a definite resistance to heat flow between bulb and well is produced by the air space between the two and the limited contacting surface. This resistance can be decreased if the air space is filled with mercury or a thin crimped metallic sheet[2] which makes good contact with both the well and the bulb. However, even this construction adds several seconds to the lag.

The comparison between the two systems is shown in Figs. 9 and 10, depicting the temperature gradient between medium and bulb during a uniform rate of temperature rise of 1° per second. In the case of ⅜" bare bulb, the entire temperature drop of 16°F. is in the film surrounding the bulb. Adding ⅝" O.D. well to the bulb increases the ratio of C/A by 200% so the drop through the fluid film for the same rate of temperature rise would be 48°F. In addition, there is a 12°F. drop across the resistance between well and bulb making a total temperature drop of 60°F. from medium to bulb. This indicates a total lag of 60 seconds, since a rate of temperature change of 1°F. per second was assumed.

The response of the bulb and well combination to gradual and step changes in temperature are shown in Figs. 11 and 12. Notice that the typical two capacity S shaped curve is apparent in Fig. 12. When dynamic compensation is applied, to this system, it is not possible to set the "Speedact" to achieve as exact a compensation for the lag of both bulb and well as it was with the simple bulb. Best results are achieved if the "Speedact" is set equal to the total lag (60 seconds in the example). The transmitter output is shown for this setting in both Fig. 11 and Fig. 12. Note the delay in reaching the true temperature in Fig. 12 and the small overpeak which results. In normal work this overpeak is generally inconsequential.

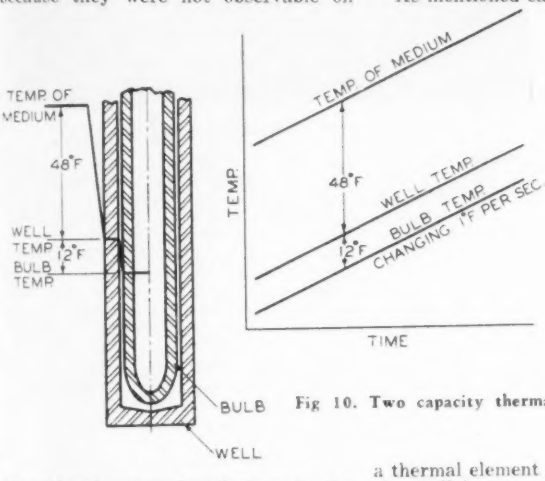

Fig 10. Two capacity thermal element.

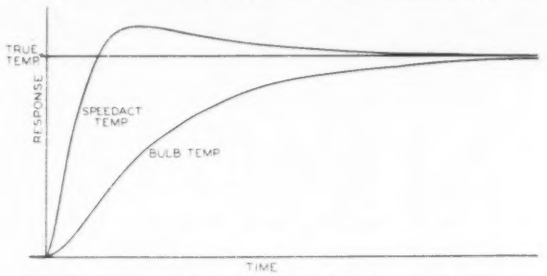

Fig. 12. Step response for a two capacity thermal element with dynamic compensation.

Conclusion

It is believed that the use of a derivative transmitter to compensate for the inevitable lag of thermal elements offers a valuable and unique tool in the field of temperature measurement and control making possible a degree of speed and accuracy not previously obtainable.

[2] Taylor "Thermospeed" sleeve for bulb and well construction.

Long Range Multi Channel Telemetering System*

By JOHN T. MENGEL†

Introduction

THE Naval Research Laboratory, in conjunction with its upper atmosphere research program, has developed a telemetering system for recording 30 channels of data originating in a missile over a distance as great as 500 miles. This system, the second such system put in operation at White Sands by the Naval Research Laboratory, is called the "Matrix Telemetering System," and has the following characteristics:

(a) Pulse time modulation of an r.f. carrier is used.
(b) 30 input channels.
(c) 312.5 samples per second per channel.

Fig. 1. AN/DKT-2 (XN-1) Telemeter Transmitting Set

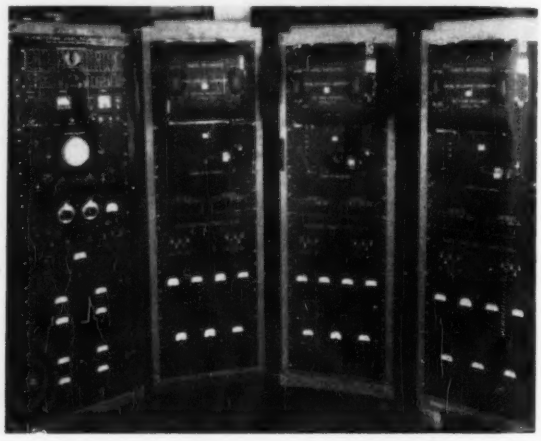

Fig. 2. Matrix System Ground Station

(d) 0 to +5 volts channel input voltage.
(e) .118 megohm input resistance.
(f) Six point voltage calibration on each channel every 10 seconds.
(g) An overall accuracy of at least ±1%.
(h) Cross talk between channels less than ¼%.
(i) Average output power in the r.f. pulse of about 4 kw.

The Telemeter Transmitter Set for the Matrix System is designated the AN/DKT-2, and is manufactured for the Naval Research Laboratory by the Hazeltine Electronics Corporation. All ground station equipment was made at the Naval Research Laboratory, and has been operated at White Sands under the technical direction of the Naval Research Laboratory field group there.

General Description

The matrix telemetering system utilizes pulse time modulation to convey thirty channels of input information. Data in the form of varying d.c. voltages is supplied to the equipment from the various experiments. The data channels are sampled successively and the whole process is repeated at a 312.5 cycle rate. A coded triple pulse identifies the start of each group and establishes a time reference framework, or matrix, of 32 intervals of 100 usec. each. Within 30 of these intervals, single data pulses occur, the position of the pulse within its interval indicating the voltage being measured on the channel. This chain of pulses is used to modulate an r.f. transmitter operating at a frequency of 1025 megacycles per second with an average power in the pulse of about 4 kw.

The ground station receives the recurrent train of pulses from the remote transmitter in a suitable receiver. The triple pulse is recognized by a discriminator and is used to generate a matrix in exact phase with the matrix in the transmitter. From this, signals are obtained at any particular time in the matrix which are used to generate the sweep voltages for the cathode ray tubes on which the data is presented as intensity modulation. Pulses generated at the beginning of each matrix interval are also applied to the display, and the scopes are photographed on a continuous film camera. There results a graph of the variation of the input voltage with time, with reference lines (which do not vary in position) between each of the data lines.

Each ground display has six cathode ray tubes upon which the thirty data channels can be applied in any combination. Sweeps of appropriate duration and timing in respect to the triple pulse are so arranged that one tube after another is swept in succession until all channels are recorded. Additional information is also supplied on the record by the application of signals to the cathode ray tube to indicate time from a standard source. The system is calibrated by periodic application of a series of voltages to each channel in turn in the airborne set.

The airborne transmitter is made in two units: the transmitter unit, and a battery box. The ground stations consist of four standard size relay racks, the first of which contains the power control panel, receiver, monitor oscilloscope, synchronization pulse discriminator, matrix oscillator, scale of 32 counter and time base generators, and power supplies. The other three racks are identical, containing the recording cameras and film magazines, recording cathode ray tubes, sweep generators, video amplifiers and power supplies. Two complete ground stations are utilized per flight, with a galvanometer recorder used in conjunction with them for recording field strength of each station, plus that of a remote station, as a function of flight time.

The overall functioning of the matrix telemetering system may be understood in relation to the major components of the equipment by reference to the block diagrams for the airborne station and the ground station, respectively. The block diagram for the airborne station shows the 10 kc. oscillator to be the initiating independent part of the circuit. The sine wave output of this oscillator is fed to a multivibrator which serves to shape it to derive a series of pulses 100 usec. apart from it. These pulses are fed through a cathode follower to a bus feeding each of the 32 tubes of the electronic commutator. These tubes are arranged as a chain so connected that only one tube can conduct at a time. As any of these thyratron tubes fires, it readies the next tube in the chain. Upon the appearance of the next pulse on the triggering bus, conduction shifts to the next succeeding tube, and so on down through the whole chain of thirty-two tubes, and the process is repeated when the last tube readies the first tube for conduction. As each of the first 30 of the chain tubes fires in turn, it generates a saw-tooth wave form which is added electrically to the input voltages for the channels. When the sum of these two voltages reaches a predetermined level (as it will sometime during the 100 usec. interval) it will cause its corresponding pick off thyratron to fire, producing a time modulated output pulse. The greater the input voltage, the sooner the sum of the input voltage and sawtooth will reach the critical voltage. The output pulses from the various channels are

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†Naval Research Laboratory, Washington 25, D. C.

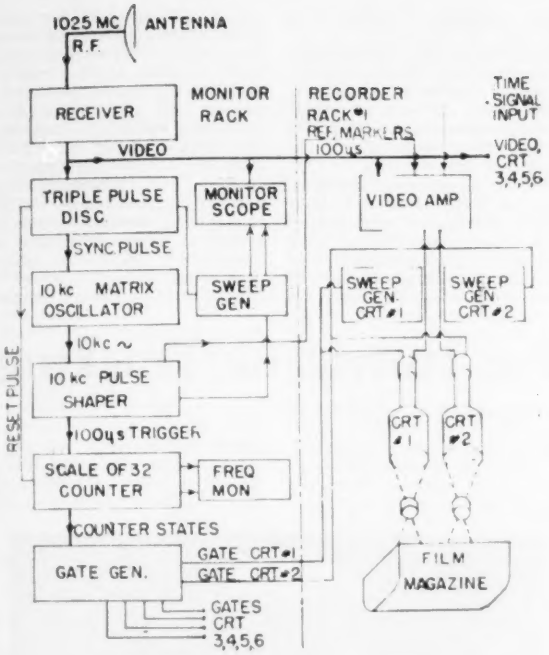

Fig. 3. Block Diagram, Matrix System Ground Station

collected on a common bus and used to modulate the transmitting tube. Also used to moduate the transmitter is the triple pulse generated at the time of the firing of the thirty second chain tube.

Each ground station comprises four racks of two main type of units. The Monitor rack contains receiving and decoding apparatus as well as a monitoring oscilloscope. Three recording racks, all identical, are used with each ground station.

Referring to the block diagram for the monitor rack, it should be noted that heavy outlines and signal lines indicate the main units and signal paths. The receiver delivers the video signal on two lines— to the recording racks and into the synchronizing pulse discriminator where the triple pulse is recognized and supplies a pulse which is used to phase and frequency lock the 10 kc matrix oscillator to the airborne oscillator. The output of the oscillator is shaped and fed into the scale-of-32 counter. This counter operates in synchronism with the chain counter in the airborne unit. It is reset by the synchronizing pulse, when necessary, so that particular states correspond in both units. By means of resistor networks from different stages of the counter, the state selector delivers a timed series of 100 usec. long pulses to a patchboard on the panel of the unit. Suitable connections are made to the trigger and gate unit to form gates for controlling the sweep circuits in the recorder racks.

There are several auxiliary units in the monitor rack. The frequency monitor determines whether the matrix oscillator is operating on the proper harmonic of the 312.5 cycle synchronizing signal, and indicates the proper frequency by means of lights on the face of the unit. The monitor oscilloscope is used for adjustment of the units and for monitoring the signal during operation. It is swept from associated generators which are synchronized from 312.5 cycle and 10 kc pulse sources. Appropriate power supplies are included in the unit, as are switches to control the operation of the recording racks.

Each of the three recorder racks contains a double recording unit consisting of cathode ray tubes and a continuous film camera. Appropriately timed gates from the monitor rack allow sweep generators to operate one after another and, at the same time, unblank the cathode ray tube so that the video pulses from the receiver in the monitor rack can be presented as intensity modulation on the tube. Necessary video amplifiers are included in this unit, as are circuits for mixing the video with timing signals and with the reference pulses generated by 10 kc matrix oscillator on the ground. There are also suitable controls for positioning and focusing the cathode ray tubes, as well as necessary power supplies.

The image on the face of the cathode ray tubes is focused on a slit on the front plate of the unit by means of two lenses, placed side by side. A film magazine is placed so that the image from both tubes is recorded on it as the film is drawn continuously past.

The total weight of the telemeter transmitter set, with batteries suitable for thirty minutes operation, is about 130 pounds. Two Willard type ER-8-28, 28 volt plastic cased storage batteries are used in conjunction with a vibrator type converter unit to provide the various plate voltage and bias supplies, plus four type ERH-25-2, 2-volt plastic cased storage batteries for the filament supplies. Total power requirements for the system are 15 amperes at 28 volts and 20 amperes at 8 volts.

The ground station operates on 110 volts, 60 cycles a.c. with a power con-

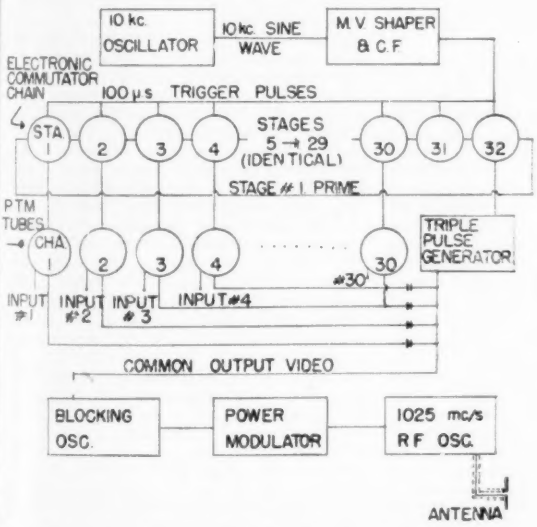

Fig. 4. Block Diagram, AN/DKT-2 Telemeter Transmitting Set

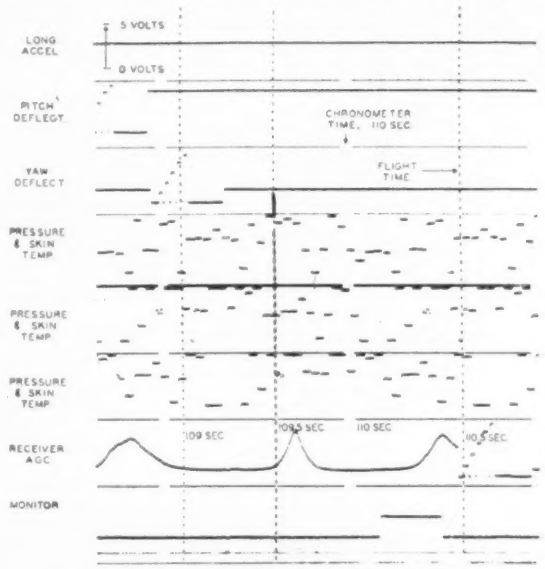

Fig. 5. Typical Record Station, Matrix Telemetering System

sumption of about 3000 watts. Voltage regulation of the primary power for these units is obtained from Sola Constant Voltage transformers. All plate supplies under 600 volts are electronically regulated against load variations. The high voltage supplies required for the cathode ray tubes are −2000 volts obtained from a conventional transformer-rectifier circuit, unregulated and +10,000 volts obtained from an r.f. power supply operated from an electronically regulated 300 volt power supply. Due to the complexity of the ground station circuits, and the number of tubes involved, two complete and separate ground stations are utilized for every flight.

In normal flights six 9½" film records of about 120 feet in length are produced, corresponding to about 450 seconds of flight. These films give a complete graph of voltage versus time for all 30 channels, and are reproduced in the form of black line paper prints.

Prior to the development of the Matrix system, the Naval Research Laboratory had developed and operated at White Sands a sequential telemetering system. This system, also utilizing pulse time modulation, sampled 23 channels of input data of from 0 to +5 volts at a rate of 180 samples per second, with a pulse output power of about 1 kw. This system utilized dry batteries for all plate supplies in the transmitter and weighed 150 pounds installed. However, due to lack of a coded synchronizing pulse and due to the method of ground recording whereby each pulse received actuated a metering circuit, the sensitivity of the system to noise was appreciably greater than the Matrix system, giving frequent losses of recorded record at ranges in excess of 90 miles. Results with the Matrix system indicate that satisfactory noise free records far beyond this range are possible.

Industrial Radar For Hurricane Tracking*

By W. F. GERDES and R. C. JORGENSEN†

Introduction

An explanation seems in order as to why an industrial corporation manufacturing chemicals has apparently invaded the province of the U. S. Weather Bureau in tracking tropical storms. The facts are that the program is not in competition with the Weather Bureau, but in cooperation with it; and it was undertaken in order to facilitate the chemical manufacture. A hurricane need come no closer than a hundred miles to cause thousands of dollars loss to the Dow Plants. The vulnerability of the site on the Texas Gulf Coast and the nature of some of its operations require that plant shut down be started about twelve hours before the occurence of hurricane winds. While the Weather Bureau's service usually provides from one to several days warning of the approach of a tropical storm, it would not be practical to keep the plant shut down at all times that a hurricane existed in the Gulf. An accurate method of tracking the storm is required that will permit shutting down only when it comes within a critical radius of the plant.

In seeking a method of pin-pointing hurricanes, several methods were considered. The standard system in the past has been reports from ships in the storm area plus direct observations by reconnaissance planes. Since most ship masters avoid storm areas, and airplane observations are very difficult and dangerous at night, this is not entirely satisfactory for keeping an accurate track of a storm.

The micro-barometric survey has been proposed for predicting the path of a hurricane. This is an extension of the centuries old technique of watching the barometer. It involves a study of the minute short time variations in atmospheric pressure, or the atmospheric pressure "waves" associated with the storm. Much work remains to be done on this system.

Micro-siesmic observations have been somewhat successful in some parts of the world. The earth vibrations caused by the storm waves and the ocean swell are recorded and analyzed. This system, however, holds little promise for the Gulf Coast because of the geological formation of this area.

The sferics method appeared favorable, and for several years Dow participated in a program based on this method. The system utilizes triangulation from simultaneous radio bearings of lightning static impulses from the storm. It requires several observation stations and very good communications and coordination among them. More work might have been done on this method, but for the promise shown by radar.

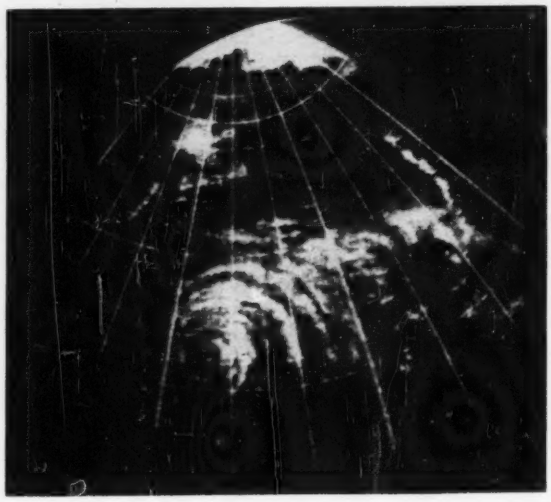

Fig. 1

The Hurricane Problem

Before proceeding further it appears proper to give a brief description of a hurricane: This will explain why it is so necessary to predict its approach hours or days in advance, and how it is possible to do so.

The hurricane is an area disturbance consisting of circular winds about a calm center or eye. Apparently most such storms originate in the tropics, but they travel far and may strike coastal areas anywhere in the tropical or temperate zones. Those in the northern hemisphere always rotate counter-clockwise, while those in the southern hemisphere rotate clockwise as viewed from above. Hurricanes are usually dangerous over a diameter of 100 miles or more, with the worst winds near the center. The calm area at the center may be several miles in diameter, and barometric pressure may be as low as 27 inches. In addition to the very severe circular winds, which may exceed 100 miles per hour, the whole disturbance moves as though it were a giant top spinning and sliding at the same time. This "forward" or sliding motion, which it is sought to follow or predict, usually ranges from 4 to 15 miles per hour. However, the storm may stay in one spot for half a day or double back on its past track.

A single storm may have a life as long as two weeks, during which it traverses thousands of miles of ocean. Once the cycle is started, energy is poured into the storm continuously in the form of warm moist air. This causes heavy rains as it spirals in toward the center and the resulting pressure drop provides impetus for continued winds and more rain. The storm usually dissipates soon after hitting land areas, but these hurricanes cause much damage and loss of life on the Gulf and Atlantic coasts. They are invariably accompanied by extremely high tides and usually by torrential rains.

The inhabitants of inland areas may have difficulty in comprehending the destruction of a hurricane, considering that the hundred-and-twenty five mile an hour winds are only a fraction as great as those of a Great Plains twister. The explanation is in the large area covered and the high water. Tides of sixteen feet have been experienced along the Gulf Coast, and forty foot storm tides are not unusual in some areas. Add to this the fact that many coastal

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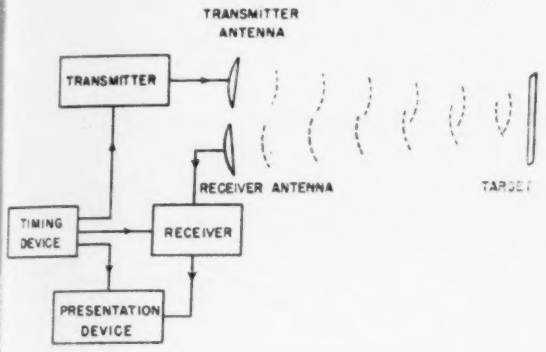
communities are from four to eight feet above sea level and it becomes apparent that cyclone cellars are of no value.

Several historic catastrophies have resulted from hurricanes, including those encountered by Columbus and the Spanish Armada. On October 7, 1737, a storm in the Bay of Bengal killed 300,000 persons, and in 1864 another in the same area killed 50,000. The Galveston storm of 1900 is a modern example of the fury of the Gulf Coast hurricane. This storm killed 2000 persons. A 1935 storm in Haiti killed 2000. In recent years the loss of life has been less, chiefly because of better warning and mass evacuation.

What property of a hurricane allows it to be detected by means of radar? During the war it was discovered that aircraft could hide in heavy rainstorms and avoid detection by some types of radar because the rain gave a radar indication of the same type as an airplane, but over a wide area. The indication was not changed by the presence of an aircraft in the rain area. Later it found that hurricanes presented a distinct picture on these radar sets because of the rain which almost invariably accompanies them. Fig. 1 shows a typical picture of the radar presentation of a hurricane on a plan position indicator. The picture is equivalent to a map or plan view of the area with the radar located at the convergence of the radial lines. These lines and the range circles form a polar coordinate reference system used to locate targets accurately with respect to the radar. The irregular white arcs represent radar reflections from the bands of heavy rains. Radar returns of this type have been found to result from hurricanes in all parts of the world, and have never been observed from any other cause. The picture shown was made from the 'scope of a 10 cm. Army radar during the 1945 hurricane which went up the Florida peninsula.



BLOCK DIAGRAM OF PULSED RADAR

Fig. 2

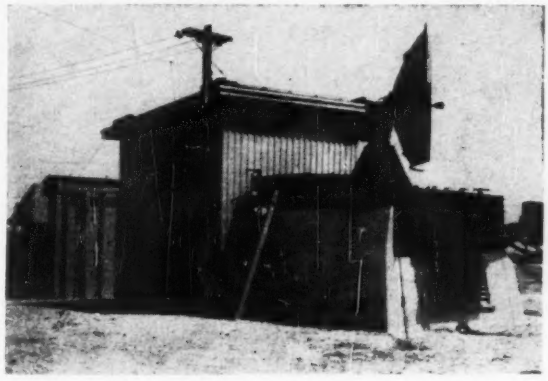


Fig. 3

How Radar Works

Radar is characterized by elaborate equipment and highly specialized techniques, but it is based upon very simple principles. Fundamentally it is an echo device, identical in principle to the methods of the steamer pilots who blew the whistle and counted the seconds until the echo returned from the shore. Knowing the velocity of sound, a simple calculation gave the distance to the echoing object. By using radio waves instead of sound, the range of the device can be greatly extended and the directional accuracy improved. Origin of the word radar is somewhat controversial, but it is said to be an abreviation of the words RAdio Direction And Ranging.

Fig. 2 shows the principal parts of a pulsed radar set in block form. The timing device serves as a program director for the entire set, controlling the transmitter, receiver, and the presentation device. Powerful pulses of radio energy are generated by the transmitter at the command of the timer. With the aid of reflectors similar to optical reflectors, these very short pulses of energy are radiated in a highly directional beam by the transmitting antenna. The receiver antenna and the receiver pick up the returned echo (if any) and send the notice of arrival to the presentation device. This device serves as a microstopwatch to measure the time required for the signal to echo from any target and gives a visual indication of this time. Usually the size and intensity of the echo and its azimuth bearing from the radar are also shown. In operation the timer causes the transmitter to send out a pulse of energy, at the same time starting the time-measuring process in the presentation device. The receiver is desensitized during the few millionths of a second that the transmitter functions so that the burst of energy will not paralyze it.

A single such pulse will give an indication of all the echo-producing objects in the path of the radio beam. However, since it may be desired to sweep the antenna rapidly through the complete 360 degres of rotation and scan the complete area covered by the radar, provisions must be made to send out rapidly recurring pulses. Thus the timer is designed to wait only the minimum time required for the reception of an echo from the maximum expected range before repeating the cycle. In the event the antenna is not rotated, recurring echo pulses are indicated in the same position on the indicator and are integrated by the persistence of the phosphor on the cathode ray tube to give a more distinct indication.

Practical radar sets may have arrangements considerably different from that shown and usually have numerous additional blocks which perform auxiliary functions. Most sets have only one antenna which functions alternately for the transmitter and the receiver through the use of an automatic switch. Power servo systems permit the operator to point the antenna in any desired direction by finger tip controls. Other devices may provide the automatic frequency control.

Radar for general use or search usually is equipped with a type of presentation known as the Plan Position Indicator. A more detailed description of this device will be of help on understanding the photographs of the radar screen. In this unit, time is measured by radial distance which a spot moves from the center of the cathode ray tube. Direction in which the spot moves is made to coincide with the direction in which the antenna is pointing. That is, the spot moves from the center upward when the antenna points north, and from the center to the right when the antenna points eastward. Direction of search of the antenna is under the control of the operator, but the direction of movement of the spot is always coordinated with it. The spot starts from the center at the time the radio wave is sent out, and moves from the center outward at constant speed. Reception of an echo is made to brighten the spot momentarily. Since travel time is proportional to the distance to the echo producing object, and time also is proportional to the radial distance the spot has moved on the indicator, this gives a bright spot for each echo-producing object in its map or plan aspect with reference to the radar set. Hence, the name Plan Position Indicator or PPI. Distance and angles may be scaled directly on this presentation.

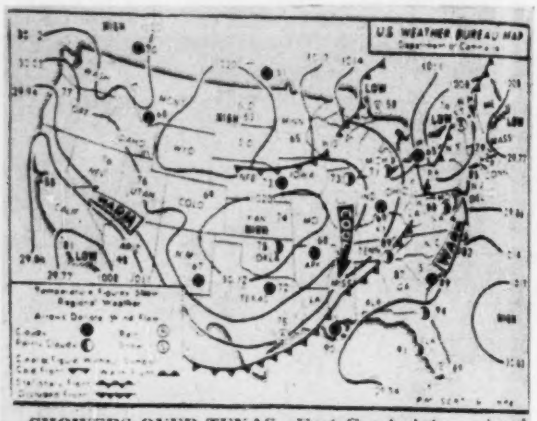
The factors affecting radio propagation and the question of what causes a radio reflection or echo have been studied in great detail in connection with the wartime radar program. In general, any conductor of electricity or any insulator with properties greatly different from the atmosphere may cause a radio reflection. The reflection is usually diffuse, comparable to light reflected from a rough surface. To produce a strong echo, the object must be of a size comparable to or larger than a half wavelength of the radio wave. However, much smaller objects such as drops of water cause some reflection; and if there are enough of these objects in a given area, an echo will be received. Calculations show that the energy returned from a drop of water varies as the sixth power of the ratio of drop diameter to wavelength.[2]

Practically, this means that 3000 Mc or 10 cm radar sets will "see" rain, while 100 Mc or 500 Mc will not. Radar operating on 10,000 Mc or 3 cm will indicate the presence of light rain or fog. Water drops of a minimum diameter of about 1.2 millimeter are indicated by 10 cm radar. Another point which should be

emphasized is that an object need not be opaque to radio waves in order to produce an echo. Just as a pane of glass may transmit 90% of the light striking it and still give a reflection, so may an object produce a radio echo and still transmit a large percentage of the signal. At times as many as three rainstorms in a row radially from a radar have been seen in the radar 'scope.

Radio energy of wavelengths commonly used in radar work travels essentially in straight lines, just as light does, and diminishes as the square of the distance from the source. Under normal atmospheric conditions there is a slight bending in the vertical plane which extends the radar horizon slightly beyond the optical horizon. To be "seen" by a radar set with its antenna at 25 feet elevations, an object at a range of 100 miles must have an elevation of about 4,000 feet, while at 300 miles an object must be about 40,000 feet high.* Thus, it is seen that there is a definite limit to the range that may be attained, even though a very large amount of power is used. Meterologists are in general agreement that the central core of a hurricane may rise to 50,000 feet, but the maximum height at which water drops are present is probably somewhat less. Because of these considerations, it appears that no radar of present design located on the ground will be able to detect a hurricane at ranges much in excess of 300 miles. Occasionally radar targets are detected at ranges far beyond the optical horizon. This is caused by anomalons atmospheric conditions which create a duct or layer through which radio waves are led around the earth's curvature. Unfortunately this phenomena cannot be relied upon to extend radar coverage.

Fig. 4



SHOWERS OVER TEXAS—East Coast states enjoyed fair and warm weather. Showers and thunderstorms were reported from the St. Lawrence valley southwestward to extreme Southern Texas. Most of the Western states had a fair, mild day Thursday.

Fig. 5

Installation Details

When it was decided to install a radar set for the purpose of tracking storms, the question of the most suitable type arose. The Weather Bureau recommended the SCR-584 or 784 since these sets are designed for about 3000 Mc (10 cm) and have adequate power. A trailer-mounted SCR-784 was purchased and certain necessary modifications were made with the assistance of Weather Bureau personnel. The installation was made under terms of an agreement whereby all data obtained with the radar would be sent directly to the Weather Bureau and would be released to the public only through that agency. A federal communications commission license was obtained for the radar station.

The set was located about two miles from the open Gulf on land about 18 feet above sea level, with a clear view seaward. The trailer was supported on a concrete foundation and a stout, well guyed building was constructed around it. An emergency gasoline power unit was housed separately nearby. Fig. 3 shows the complete installation.

The SCR-784 is a gun-laying radar with automatic tracking arrangements designed to cause the antenna to continuously point at a fast moving target once it has been placed "on" it. Needless to say, this feature is of no value in tracking storms. Other features of a gun-laying set are very short pulse width or length of time during which energy is transmitted, and relatively short design range. This does not imply a lack of power, but rather a short listening period between transmitted pulses. The peak power of the set during the .8 microsecond transmitted pulse is 250 kilowatts, or five times that of the most powerful commercial broadcast station.

Modification of the set for the weather work began with a slowing of the pulse repetition frequency to give more listening time between transmitted pulses. Additional multivibrator stages were added to the timing circuits to give a frequency of 188 pulses per second, which permits reception of echoes from objects 300 miles distant. Then the presentation unit was modified to cause the cathode ray spot to sweep more slowly, corresponding to the time required to receive echoes from the longer range. Multiple ranges of 100, 200, and 300 miles were provided, with a selector switch to choose among them. It must be recognized that range as used here refers to the distance equivalent of time of sweep of the indicator oscilloscope. Any arbitrary range may be placed on the 'scope up to the limiting time interval between transmitted pulses; however, there is no assurance that echoes will be received from these wholly arbitrary ranges. Range marker circuits were changed to give reference marks on the PPI 'scope corresponding to ranges of 20 mile increments. These assist in determining the exact range to a target, since the indicator circuits may have faults which result in non-linearity of the picture.

This completed the necessary modifications, but several others were made in the interest of improved efficiency. A larger parabolic antenna reflector was installed in order to focus the radio waves into a sharper beam and thus give a higher concentration of energy and improve ability to resolve targets near one another into separate pictures rather than merging them into a solid pattern. The original military design required very high resolving power, and achieved it by spinning the very slightly off-set antenna to produce a radio beam that rotated about the axis of the antenna. However, this was effective only in the automatic tracking circuits and did not improve the picture on the PPI oscilloscope. The larger reflector improved the PPI resolution as well as giving the effect of increased transmitter power and receiver sensitivity.

The slowing of the pulse repetition frequency previously mentioned resulted in a reduction in the average energy transmitted by the station, since each pulse contains a definite energy and the number per second was reduced. In order to increase this average energy output, the pulse width or time during which the transmitter is energized was increased from the original .8 microsecond to 1.6 microsecond. In general, average power is unimportant so long as peak power is maintained, but a pulse of longer duration improves the signal from a diffuse object or one with depth, such as a rainstorm. This greater pulse width gives poorer resolution in range, but it is still more than adequate. From consideration of the speed of radio waves as 186,000 miles per second, or one two-way mile in approximately 11 microseconds, a pulse of 1.6 microseconds duration gives a possible resolution in range of about one-seventh mile. However, this cannot be realized on a small PPI presentation. An expanded sweep of a portion of the listening time interval would show details of

* $R = 1.43\ (\sqrt{H_1} + \sqrt{H_2})$ Where R is range in miles and H_1 and H_2 are heights of radar and target in feet.

this order. While this would be interesting, it does not come within the scope of the program for practical hurricane tracking. The angular resolution of the modified equipment is of the order of two degrees, which means that at a range of 100 miles isolated objects less than four miles apart will have their echoes merged. This difference between angular and range resolution causes point targets to produce elongated pictures with the long axis tangent to range circles.

Other modifications made included installation of a new pre-amplifier and a larger PPI tube. The pre-amplifier for the receiver was of newer and more efficient design, giving better receiver performance. A larger PPI tube added nothing to range or sensitivity of the equipment, but permits a more detailed study of echoes. Camera equipment was arranged to permit rapid photographing of the screen with convenient means for identifying each picture as to date and hour. An automatic camera was also arranged to take a picture every minute. When projected as a movie film, the record of this camera should be very interesting. As modified, the equipment is considered entirely satisfactory for weather work. The most serious limitation is that imposed by the horizon, or the curvature of the earth.

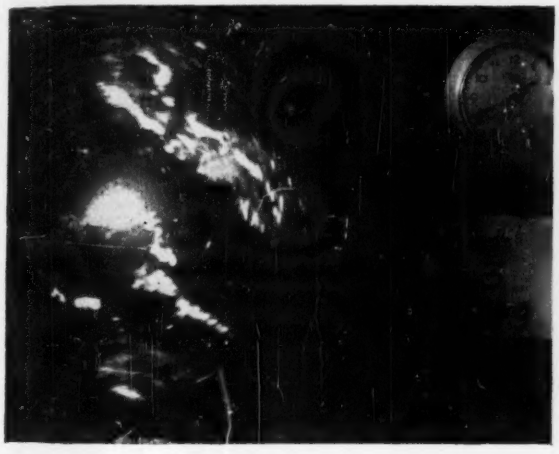


Fig. 6

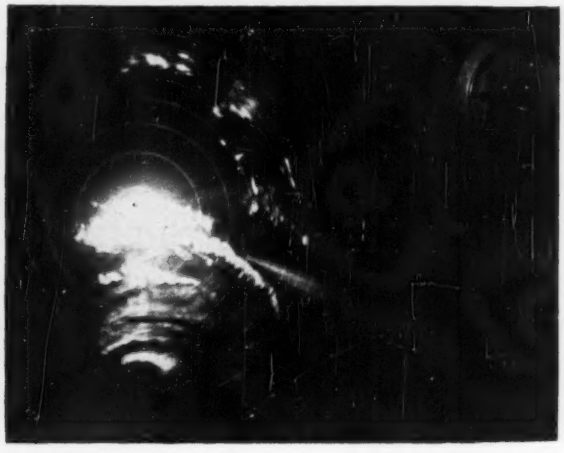


Fig. 7

Results

After the equipment was installed and modified, many observations were made to test the range and accuracy. Thunderstorms and isolated rains were observed and telephone calls were placed to verify the actual weather at the points where rain was indicated. Agreement was surprisingly good. This process was sometimes rather amusing when a distant airport or weather station was called and the attendant was asked a series of questions apparently based on mindreading or intuition. Questions such as, "Has it been raining there for about fifteen minutes?" or "Did the rain storm approach from the northeast?" usually evoked surprise and amazement—at least when the answers were affirmative. Some cases of disagreement were apparently caused by rain in the upper atmosphere which evaporated before striking the ground. Results were consistent enough to indicate that rain will always be indicated. Many storms have been observed at ranges greater than 200 miles, at least one at 240 miles being vermed. Echoes from 280 miles have been observed. Several times the radar screen has presented a picture of a line squall that agreed very closely with a front indicated on the official weather maps. Figures 4 and 5 indicate one case of this type. Geographical features were dubbed in to better orient the 'scope photograph. This picture also illustrates a case of the radio waves penetrating 80 miles of solid rain and still retaining power to produce an echo from rain 100 miles distant.

A program was set up for daily observations during the hurricane season —from the middle of June to the first of November. Daily observations are considered sufficient at times when no hurricanes are known or suspected to be within range of the equipment. When general weather observations indicate the likelihood of storms, the Weather Bureau requests that additional observations be made. The results of all such observations are sent to the Weather Bureau.

In the event that a tropical storm is known to be approaching, the equipment is manned continuously. A weather consultant is on hand to interpret the results and direct the experimental program. Experience during the war indicates that considerable information about a hurricane may be revealed by one observation on the radar screen. The center or eye of the storm is usually well defined as a clear area completely or partially surrounded by heavy rain. Even before the main part of the storm comes within range, the squall line associated with it may provide some information. These squalls may be from 40 to 100 miles from the center and they are thought to run at right angles to the line of progress of the storm. It is also generally acknowledged that rains are heaviest in the right front quadrant of the moving storm—this is based on storms in the northern hemisphere, which always have counterclockwise rotation as viewed from above. When observing a storm moving radially, that is, approaching the radar, the movement should be apparent from observations taken 15 minutes apart. This contemplates a speed of four miles per hour and a range resolution of the radar of one mile.

As an experimental program, efforts will be made to obtain a vertical profile of the hurricane core by taking successive photographs as the angle of antenna elevation is increased. If this is successful at all, it will probably be at rather short ranges, since the angular resolution is hardly adequate for this.

Fortunately, the hurricane data obtained thus far with this equipment has been of a negative nature. That is, the first hurricane season and a portion of the second have elapsed with no hurricanes having presented themselves for observation. This does not dampen enthusiasm for the program in any way. The range and reliability of the equipment having been proved on rainstorms, Company management can rely on the absence of hurricane patterns with as much confidence as if a storm were pictured on the screen—and with considerably more complacency. It must be acknowledged that the hurricane which struck New Orleans on September 3, 1948, passed within 300 miles of the radar. The Weather Bureau's track shows it passing about 270 miles to the east of Freeport. No indication of a hurricane or even of rain was obtained during its course. However, this particular disturbance barely qualified as a hurricane, the highest wind velocity being 70 miles an hour. Undoubtedly it did not reach the altitude required for radar observation at this extreme range.

Conclusions

No attempt will be made to draw conclusions regarding the radar method of tracking hurricanes. The method was verified by numerous cases during the war, the most widely publicized one being the September 14 to 15, 1945, hurricane which was tracked up the Florida Peninsula by a 10 centimeter radar at Orlando.

The equipment as installed and modified at Freeport, Texas, has been found to be accurate and reliable. Although no hurricane has been observed, results on rainstorms indicate a conservative range of 200 miles. From the vewpoint of Company management, the program has been practical and valuable in maintaining uninterrupted plant operation during threatened hurricanes. As a consequence of the demonstrated practicability of radar equipment and the previous success of the Army in tracking hurricanes, it seems very desirable to have overlapping coverage of the entire Gulf

and lower Atlantic Coasts. With a chain of these modified weather radar stations and the increasing use of general navigational radar by ocean vessels, tremendous improvements in detecting and tracking hurricanes should be realized. Besides permitting intelligent evacuation of threatened areas, this will provide a powerful tool for expanding the knowledge of these terrible storms.

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History *of* Bellows-actuated Flow Meters*

By CLAUDE B. NOLTE, Vice President, Barton Instrument Corporation, Los Angeles, Calif.

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Glass-tube manometers for measuring differential pressures were known as far back as the middle ages and may have been used by Roman engineers for measuring static pressures in the great waterworks system in Rome. These pioneer engineers were aware of methods of regulating water flows. The service connections on the city water mains were fitted with stopcocks much the same as we use today. Beyond each stopcock a straight, smooth restriction tube of definite diameter and length was placed in the piping to limit the amount of water each householder might withdraw. Presumably, the customer paid so much a month for a certain size tube, a greater amount for a larger one. Thus, although flow metering as we know it today began sixty years ago, the rudiments, at least, were recognized nearly 2000 years ago.

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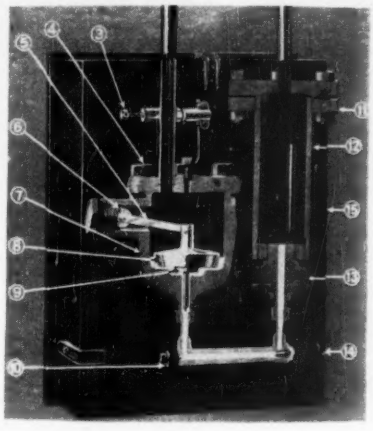

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may be readily transmitted outside the pressure casing through a system of levers and shafts. A seal is made around the main transmission shaft by a precision lapped bearing of stainless steel; or magnetic couplings do away with the need of stuffing-boxes, etc., for sealing shafts. In its present form, the float type manometer is widely used in industry. For many applications, it is doubtful indeed if any other mechanism will ever take its place. Still, it does have limitations.

The float type manometer doesn't lend itself readily to use aboard aircraft where the instrument may be subjected to forces of a lateral type which tend to drive the float against the case or its guide rods. The float type manometer may be made portable but it must be leveled precisely to obtain accurate results. Moreover, the weight of the mercury alone makes a lightweight unit difficult to produce. If an excessive differential pressure is applied, the mercury may be blown out of the instrument and lost. Even though check valves and mercury catch-pots have been devised to prevent or reduce these losses, mercury consumption is still high. This is not only caused by over-ranging, but by the activities of the mercury thief as well. A float type recorder contains enough mercury to make an evening's work for the thief quite profitable.

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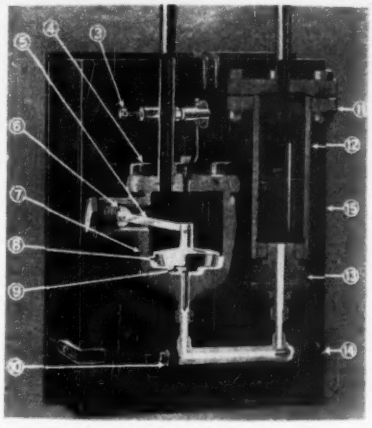

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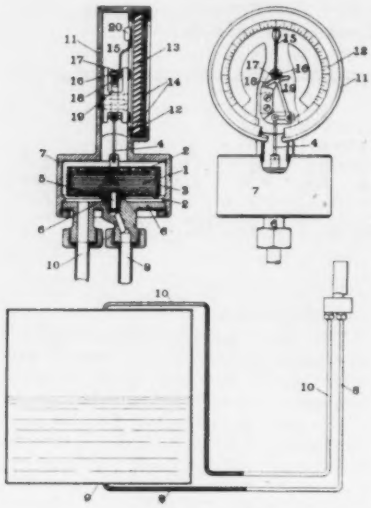


Fig. 2

deflection of a flexible metallic bellows. The bellows-actuated meter may be made quite compact. The size of the meter doesn't change appreciably with increases in differential pressure range. Changes in range may be made without replacing major parts. The bellows type meter doesn't require mercury or any other liquid to balance out the differential pressure, hence it may be made light and quite portable. The bellows type meter lends itself admirably to the use of a torque-tube instead of a pressure-tight bearing or stuffing-box for the transmission of bellows position to the indicating or controlling mechanism. This in turn, results in fewer service problems, especially in high-pressure gas measurement.

From a theoretical view, the bellows-actuated meter has certain positive advantages over a liquid-manometer type of meter. In commercial use, however, some definite problems are encountered. Commercially-available bellows were, for a number of years, not entirely suitable. Spring rates and effective areas weren't constant: variations in these two factors introduced complications in calibration, particularly when the bellows was to be replaced by the instrument user. The high degree of sensitivity of bellows type recording meters was a handicap in handling pulsating flows because the instrument response could not be readily damped.

By far the most serious problem was the protection of the bellows against damage if an excessive differential pressure should be accidentally imposed across the instrument. If the bellows was made sufficiently strong to withstand the full operating pressure imposed across it, the deflections for normal differentials required extensive magnification. This introduced the problem of combating friction if the magnification was done mechanically, as is the case in most industrial applications. A bellows capable of withstanding high internal pressure is more subject to hysteresis because of the geometrical relationship between bellows diameter and bellows metal thickness. As a compromise it was necessary to use a relatively fragile bellows and depend upon relief devices or careful operating procedures to prevent bellows damage.

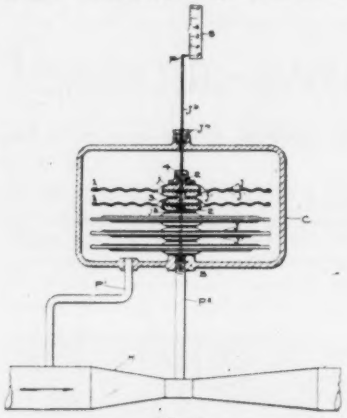


Fig. 3

Flexible metallic bellows were proposed for use in pressure-measuring mechanisms shortly after the work of Venturi, but, unfortunately, practically no information has been handed down to us about these early devices. Eugene Bourdon, the capable Frenchman who is credited with inventing the static pressure element bearing his name, also patented a bellows-actuated aneroid barometer in 1852.

The United States patent office offers us the opportunity to take some interesting glimpses into the history of bellows-actuated differential pressure gages, and, incidentally, take a look at trends in the development of bellows manufacturing methods as well.

A patent was granted in 1901 for a bellows-actuated boiler water-level gage (Fig. 2). To overcome the problem of stuffing-box friction and leakage, the inventor simply enclosed the entire mechanism (movement, pointer, scale and all) inside a case with a glass cover. The higher pressure, represented by the steam pressure plus the liquid head in the condensing leg, was conducted to the outside of the bellows, while the lower pressure at the base of the boiler (produced by the steam pressure plus the liquid head in the boiler) was introduced inside the bellows. Although the inventor also mentioned the use of this gage as a method of measuring pressure drop across the valves, he seems to have been wholly unaware of its possibilities as a flow meter. This was unfortunate, because it would have worked admirably with a Venturi tube as an indicator of low-pressure water flows. In fact, about five years ago, a manufacturer, prominent in the water-works field, placed a gage on the market that operated on this very principle.

The next patent, granted in 1911 (Fig. 3), is of interest because it is the first one to describe a bellows type meter for use with a primary device (in this case a Venturi tube) for measuring flow rates. This inventor proposed the first system for preventing damage to the bellows as a result of excessive flow rates. The bellows was designed to compress with increasing differential pressure and the bellows convolutions were shaped to fit into one another and thereby prevent distortion, even if the assembly closed completely. The proposed method of transmitting bellows motion outside the pressure chambers was wholly unsatisfactory, and this may have led to the development of a mechanism patented in 1913, using a pair of bellows in conjunction with a flexible diaphragm (Fig. 4). The movement of the diaphragm and the bellows, upon application of pressure differences to chambers 1 and 2, was transmitted to the indicating mechanism through a rod connected to the inner end of one bellows. Because of the limitation imposed by the strength of the transmitting bellows, this unit could be used only for relatively low static pressures.

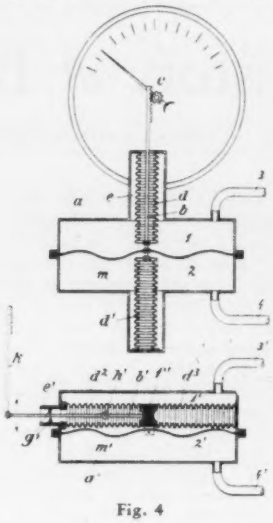


Fig. 4

The second idea shown in Fig. 4 is an alternate method of combating the problem of pressure-bearing leakage and friction. The bellows assembly was to be bent by the flexing of the diaphragm. The rod b' passing through the bellows was pivoted at the fulcrum g'. Movement of the diaphragm would cause the outer end of the rod b' to move up and down. It is of interest to recognize that modified versions of this method of transmitting motion from within high-pressure vessels are being used today by two different manufacturers.

In 1928 a West Coast manufacturer patented and produced an instrument that was unique because it represented the first use of the torque-tube in conjunction with a bellows. This was really a significant innovation because, even though pressure-tight bearing construction had been improved by better techniques in lapping, these bearings still required lubrication. Lubricants that won't dissolve in certain petroleum products, for example some of the solvents, aren't completely satisfactory. In some industries, the lubricant may be slowly altered by chemical changes which effect lubricant viscosity with resultant increases in bearing friction. Moreover, there simply isn't a universal lubricant. With a torque-tube, all these problems disappear.

The construction and operation of a torque-tube as applied to instruments is familiar to most instrument users; nevertheless, let us review the device briefly. First of all, the torque-tube is a mechanism for transmitting rotary motion through the walls of a pressurized chamber without the use of stuffing-boxes or closely-fitted shafts and bushings. It consists of a thin-walled tube, rigidly attached at one end to the wall of the pressure chamber. Passing inside the tube and rigidly attached to its inner end, is a shaft. The shaft projects beyond the tube outside the pressure chamber. The inner end of the tube and the outer end of the shaft are supported on suitable bearings.

When the inner end of the tube and shaft assembly is rotated, the thin-walled tube twists because its other end is firmly anchored into the pressure chamber wall. The outer end of the shaft, being freely suspended, turns through the same angle as the inner end of the tube. In this way, the rotary motion imparted to the inner end of the torque-tube assembly also appears on the outer end of the shaft. At the same time, fluid pressure applied to the inner end is completely and positively sealed without any chance of leakage.

The first instrument to incorporate this torque-tube had built-in over-range protection in the form of a thin soft-metal plug mounted in an auxiliary bellows separating the high and low-pressure chambers, and was provided with a mechanism which punctured the plug when the differential pressure became too great. After the instrument had been over-ranged, it was necessary to replace the safety plug before it could be put into service again. This system of over-range protection was positive because there were no valves to stick; but it, too, became ineffective when called upon to protect the bellows against extremely high differential pressures.

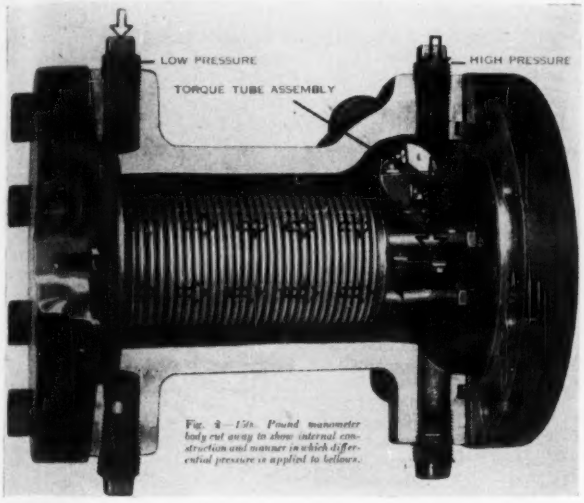


Fig. 5—150-Pound manometer body cut away to show internal construction and manner in which differential pressure is applied to bellows.

Fig. 5

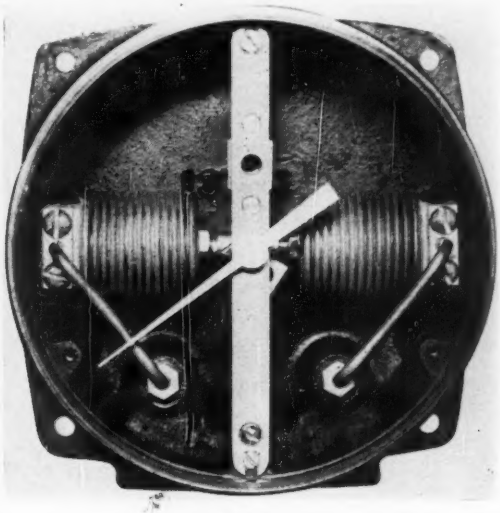


Fig. 6

In 1941, at the request of certain chemical companies, another manufacturer developed the bellows-type flow meter shown in Fig. 5. It was outstanding because, for the first time, a stainless steel bellows was used. Although it didn't contain a relief device, the use of a torque-tube made it somewhat similar to the unit that appeared in 1928. Differential pressure range was determined by the torque-tube strength rather than by a calibrating spring. Even though it was subject to the problem of bellows damage as a result of excessive differential pressures, this instrument made important contributions to the war effort, in atomic energy work, and in the HF Alkylation plants designed to produce 100-octane aviation gasoline.

During the war a special submarine gage was required to measure differential pressures that were of essentially the same magnitude as the static pressure. To simplify the unit by avoiding the use of a pressure bearing or torque-tube, a dual bellows design was selected (Fig. 6). The closed ends of the two bellows were jointed by a stem, from which the indicating mechanism took its motion. The two pressures, whose difference was to be measured, were introduced into the bellows.

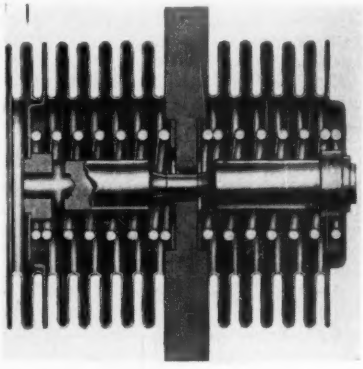


Fig. 7

Now this gage wasn't particularly important as a product, but it was important as the germ of an idea. As we've mentioned before, the innumerable attempts to design automatic valve arrangements to protect the bellows mechanism were unsatisfactory for one reason or another. The submarine gage started a new train of thought (Fig. 7). Suppose we were to turn this double bellows affair inside out; put the line fluid on the outside and retain the center stem holding the two bellows ends together. This center stem would pass through a plate on which the bellows could be mounted. Likewise, the stem would bear two valves, one of which would close against the center plate when the bellows were displaced beyond the normal travel in either direction. Now let's completely fill the inside of the bellows with a clean non-corrosive liquid. When the bellows is shifted as a differential pressure is applied, this liquid must travel from one bellows chamber to the other through the annular space between the bellows

center plate and the bellows stem. When the maximum bellows travel has been reached, one valve closes and liquid may no longer flow from one chamber to the other. Because the liquid may not escape, the bellows will not be destroyed by the imposition of additional differential pressure.

A simple way to lick the over-range problem, isn't it?—and just as effective as it is simple! The valves always close because they are in a clean liquid; they are free-floating and therefore cannot bind or stick.

Although this looked like the answer to the question of bellows damage, there were still some problems to solve. Experiments with an early model revealed that changes in fill-fluid volume as the result of ambient temperature variations would cause appreciable shifts in zero reading. With the dual bellows construction, the entire assembly would shift in the direction of the larger bellows when the internal pressure increased. Furthermore, the change in bellows diaphragm shape altered the spring rate, resulting in changes of differential range.

These difficulties were corrected by incorporating a chamber whose volume would increase or decrease readily without major changes of internal pressure. The temperature compensator was added beyond the bellows end-plate on the high-pressure side of the assembly. A hole in the inner end-plate permitted the passage of fill-fluid into or out of the floating bellows. Thus, as the liquid expanded, the compensator bellows changed shape to accommodate the additional volume. True, the internal pressure in the bellows increased a trifle, but the effect was negligible compared to the pressures built up in the original design. Fig. 8 is a cross-section through the first instrument made (1943) using the temperature-compensated rupture-proof bellows construction.

To utilize all the advantages of rupture-proof bellows design, a torque-tube, together with stainless-steel construction, was incorporated in 1948. As an additional advantage, the calibration spring was located outside the bellows assembly in the low-pressure housing where it could be reached easily when a change in range was to be made.

It is important to recognize that the torque-tube was placed inside the bellows assembly where it is always in contact with a controlled fluid. Such construction makes it practical to mount the torque-tube on needle bearings while the movement of the bellows is transferred to the follower arm through a miniature ball-bearing. That this construction results in a high degree of sensitivity is demonstrated by the fact that pointer motion may be observed with a change in differential pressure of only one part in 4000 at high-pressure levels, currently up to 3000 psi. This means that changes in pressure differential of 0.025 in. water column will result in pointer travel in an instrument calibrated for 100 in. W.C. Naturally, a magnifying glass is necessary to observe the pointer movement, but it actually is discernible.

Commercially-available bellows didn't make possible full use of the potential advantages of the rupture-proof construction. Actually, a bellows of paper-thin metal was required; in fact, within limits, the thinner the better. At the same time, a fairly large bellows was desired in order to supply ample power to drive recording and controlling mechanisms.

Because a bellows is, after all, a special form of spring, the characteristics of the metal should approach those of spring steel as nearly as possible. To produce efficient bellows forms, it is necessary to draw the raw sheet stock into fairly complex shapes. This precludes the use of spring-temper raw materials.

Even though commercial methods had been developed for assembling stainless-steel diaphragms into bellows using the helium arc welding process or the atomic hydrogen process, there were two objections. The thinnest material that could be assembled was far too thick for a suitable bellows; furthermore, the welding seriously altered the temper of the metal at the location of the weld. To produce bellows with the desired characteristics, an unusual seam-welder was developed to weld the 0.003-in. thick diaphragms into completed bellows, and also weld the bellows to heavier end fittings (Fig. 9).

Bellows-actuated flow meters are used for the same applications as the mercury float type manometers; that is to say, flow measurement of liquids and gases in a myriad industries extending from swimming pools to atomic energy plants. However, the meters employing the rupture-proof bellows principle are suitable for certain unique jobs.

If the low-pressure housing of the gage is left open to atmosphere and the high-pressure side connected to a highly-variable pressure, the unit is capable of acting as a low-pressure gage with over-range protection. In some industrial and naval applications, it is essential to measure low pressures quite accurately, which dictates a unit with low range; however, the pressure will often rise to high levels. The use of the rupture-proof construction makes it unnecessary to disconnect the low-pressure gage when higher pressures are present.

A similar application is found in pressure switches which must withstand high normal pressures and yet open or close when the system pressure approaches atmospheric pressure. The rupture-proof principle makes such switches quite simple and absolutely reliable. With the more commonly used Bourdon-tube-actuated switches, it's difficult to maintain the trip pressure under such operating conditions. The tubes have an accuracy of about 1 percent of full range; if the normal pressure is 1000 psi. and the unit is to trip at 15 psi., the basic accuracy of 1 percent or 10 psi. makes this a bit difficult. The switch might trip at 25

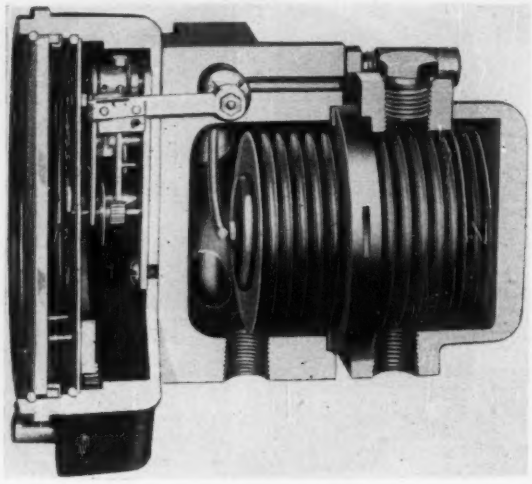


Fig. 8

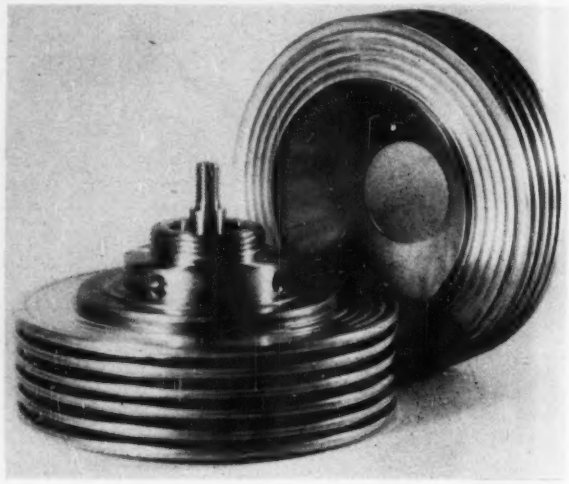


Fig. 9

psi. or it might trip at 5 psi. On the other hand, a rupture-proof bellows actuated switch would trip between 14.8 and 15.2 psi.

Occasionally it may be necessary to measure pressures at high levels with a degree of accuracy beyond that of a pressure gage. This may be done readily by using a rupture-proof bellows-actuated indicator and a dead-weight tester. Now the tester normally has an accuracy of 0.1 percent of the pressure being measured, whereas, for comparison, a good pressure gage has an accuracy of 0.5 percent of its full range. The rupture-proof bellows-actuated differential pressure indicator is installed between the pressure to be measured and the dead-weight tester. Therefore, it measures the difference between the two. Because the indicator, with a low differential range, has a degree of accuracy that is high compared with the system pressure, it is possible to obtain accurate pressure measurements at unusually high pressure levels. The use of the rupture-proof indicator prevents the accidental release of system pressure that would almost certainly occur if the dead-weight tester were employed alone.

A rupture-proof bellows type differential pressure indicator is commonly used as a gage for level measurement of refrigerated liquified gases such as CO_2. Essentially it's a boiler level gage operating in reverse. An uninsulated piece of pipe, horizontally located at the bottom of the tank, acts as a vapor generator. The generator supplies gas to the high-pressure side of the indicator while the top of the tank is piped to the low-pressure side. The entry of liquid into the gage and small piping is prevented by the constant supply of CO_2 gas that is available from the generator to increase the pressure in the piping and instrument when the liquid level increases.

Naturally, the outstanding advantage of a meter that is not damaged by over-range lies in the fact that the instrument will not be harmed if an operator accidentally opens the valve that vents one side of the instrument to atmosphere, or similarly, if the block valves are opened incorrectly when the instrument is being placed in service. With a rupture-proof bellows-actuated flow meter, it is quite permissable, when placing the unit in service, to open one block valve with the by-pass valve closed, even though the instrument may be connected to a system with line pressures of 1000, 2000, or even 3000 psi.

To test the efficiency of the rupture-proof bellows design, one company, prominent in the oil and chemical field, connected a rupture-proof bellows-actuated indicator across the discharge outlets of a double-acting reciprocating pump. The instrument was installed in such a way that each time the pump stroked, 1500 psi. was applied to one chamber and approximately 1200 psi. to the other. With each reversal of the pump piston, the pressures were applied to alternate chambers on the meter. The instrument calibration was 25 in. W.C. or approximately 1 psi. In other words, the over-range differential pressure applied to the instrument was 300 times its normal range. The plunger of the pump stroked approximately 20 to 25 times per minute, and the tests were continued for 20 days. The net result was an application of an excessive differential pressure (alternately in the normal direction of differential and then in the opposite direction) approximately half a million times. At the conclusion of this test, neither the instrument's calibration nor its zero was appreciably altered. In fact, the instrument is still being used in the experimental department of the company which conducted these tests.

Because a rupture-proof bellows-actuated flow meter is automatically self-draining, the seal pots sometimes used when wet gas is being measured aren't necessary. Any liquid that may condense inside the meter chamber will automatically drain out of the instrument housing because the fluid being measured only contacts the outside of the two sets of bellows. Similarly, if a rupture-proof bellows-actuated flow meter is used on a gas line where there may be intermittent surges of liquid, any liquid that may rise into the bellows chambers will drain out completely and automatically. At the same time, the differential pressure created by the passage of liquid through the orifice instead of gas won't damage the instrument in any way.

Of interest too, is the ease of installation of the bellows type meter. The instrument need not be leveled precisely; in fact, it would function upside down if there were a need for such a novel installation. Of course, there's no need to fill the unit with mercury: merely pipe it up and it's ready for use.

Whenever bellows type recording meters were employed in the past for industrial applications where pulsating differential pressures were encountered, they were found to be unsatisfactory. Indicating instruments could be used on slowly pulsating services without diffculty, but this was not true of recording meters. Even non-periodic pulsations with a time interval of two minutes between pulses would produce a broad trace on the chart. More rapid changes would form ink blots as well as cause rapid ink depletion.

This trouble plagued the rupture-proof bellows construction just as with the older single-bellows style, even though the former design provided a degree of inherent damping. The bellows fill-fluid, in flowing from one bellows chamber to the other, reduced the instrument's response rate. In 1949 an internal, completely adjustable pulsation dampener was included in the basic rupture-proof bellows design. The annular restriction between the two bellows chambers was drastically reduced by the introduction of a floating piston ring on the bellows center stem within the center plate (Fig. 7). The flow of fluid between the two chambers as a differential pressure was applied was, thereby, greatly slowed down. To provide for adjustment to operating conditions, an O-ring-sealed adjustable needle valve by-pass around the piston ring was supplied. Instrument responsiveness could be selected from ten seconds to five minutes for full-scale travel. The selection could be made while the instrument was in service and under pressure. There could be no danger of unequal snubbing of the meter as could be done with two external line dampeners; the dampener valve and mechanism never contacts the line fluid, so it will operate in a trouble-free manner with no plugging or sticking.

With the addition of the internal adjustable pulsation damper to the earlier developments of the torque-tube and rupture-proof bellows construction, differential-pressure-measuring apparatus is now available that not only offers all the inherent advantages of bellows type meters but also provides the desirable features of mercury-float type instruments without the service problems that are inextricably linked with them.

We've talked of the early as well as the recent developments in a phase of the new science and engineering born sixty years ago. It will surely be forgiven if we attempt a fleeting glance at the future. To do so requires the turning of more pages in history. A few years before the development by Herschel of the Venturi tube, Clerk Maxwell published the first comprehensive paper on feedback mechanisms as related to steam engine governors. You will recall that most of the modern control devices are built around the basic principle of feedback. Thus, at roughly the same time, the beginnings of control mechanisms, as well as a phase of measuring mechanisms, had their inceptions. It's fundamental that *before a condition can be controlled it must be measured.** Therefore measuring and controlling devices are closely linked.

About eighteen years ago it became increasingly clear that the mechanisms of control developed by man and the mechanisms of control within man are remarkably similar. The phenomenom known to the instrument engineer as "hunting" is closely related to what the physician calls clonic contractions in the epileptic patient. Complex calculating machines go through a process of "learning" over a period of operating time and, if subjected to conflicting impulses, may break down and react as an insane person does; moreover, the "cure" for such calculating mechanism insanity is shock—the same as in the human being. This may be interesting enough, you say, but what has it to do with Flow Meters? No doubt about it, the connection isn't concrete—we are just looking ahead in a broad way.

Man is now able to produce control mechanisms capable of performing the functions once reserved for the human

*"Fundamentals of Instrumentation" (1932).

mind. The aircraft fire control computers developed a quarter-century ago are outstandingly superior to the manually-operated devices; and those developed during World War II are even more efficient. Refineries are capable of making products requiring a degree of control that would be entirely impossible using the hand control methods of thirty years ago. Indeed, during the past ten years the refinery has become a "manless plant." Year by year the evidence grows to show that the *completely* automatic factory for mass production of standardized products is not far away. What changes may such skills and knowledge make in the economy of tomorrow's world?

A few generations ago, the world experienced the industrial revolution when machinery replaced man's muscles to provide the power in manufacturing goods. There appears to be evidence that a second industrial revolution is in the making as the result of man's potential ability to produce automatic-control systems capable of doing routine "thinking." The changes in the world of our children and grandchildren may well be as powerful as the effect James Watt's steam engine had on the generations succeeding his day.

TECHNICAL SOCIETIES

Society for Applied Spectroscopy

February meeting, Tuesday the 7th. Informal dinner, 6 p.m. at Tosca's, 118 Fulton St., New York City. Reservations are not necessary. Meeting, 8 p.m. at Socony Vacuum Training Center, 63 Park Row, New York City. Contributed Papers by Society Members:

"Three-line Method of Heterochromous Photometry" by Dr. Milton Green, Squier Signal Laboratory.

"Spectrochemical Analysis of Lead and Zinc in Ores" by Isidore Adler, U. S. Customs Laboratory.

"Rapid Identification of Plastics by Infrared Absorption Means" by Harry Hausdorff, General Cable Corp.

"Investigation of Kodak I-N and I-L Spectroscopic Plates" by R. Hoffman, Socony Vacuum.

"Spectrochemical Determination of Magnesium in Low Alloy Steel" by Neil Gordon, International Nickel Co.

—ROLGER W. LOOFBOUROW

The Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy and Exposition of Modern Laboratory Equipment.

Sponsored by: Analytical Division, Pittsburgh Section, A.C.S. and Spectroscopy Society of Pittsburgh.

William Penn Hotel,
February 15-17, 1950

TENTATIVE PROGRAM

Wednesday morning. C. Manning Davis presiding.

Welcoming Remarks: R. A. Friedel, Chairman, Spectroscopy Society of Pittsburgh; T. C. Bryson, President, Analytical Division, Pittsburgh Section, A.C.S.; Mary E. Warga, University of Pittsburgh; Henry Freiser, Chairman of Exposition.

Philip J. Elving, The Pennsylvania State College, "The Fundamental Operations of Analytical Chemistry"

George R. Harrison, Massachusetts Institute of Technology, "Progress in Spectrographic Instruments."

Afternoon Session, R. G. Russell presiding.

William Seaman, American Cyanamid Co., "The Industrial Analytical Chemist in a Changing Scene."

J. Convey, Canadian Bureau of Mines, "Spectro Chemistry at the Bureau of Mines in Ottawa."

Chester M. Alter, Boston University, "An Analysis of Analyses."

Van Zandt Williams, Perkin-Elmer Corp., "Recent Developments in Infrared Spectrometry".

Wednesday evening, Conference Dinner, Toastmaster, J. R. Anderson; Main Speaker, H. V. Churchill.

Thursday morning. Henry Freiser presiding.

Harvey Diehl, Iowa State College, "Titrations With Ethylenediaminetetraacetic Acid."

H. H. Willard, University of Michigan, "The Determination of Fluoride."

George A. Perley, Leeds & Northrup Co., "Electrode Problems in Electrometric Measurements."

E. St. Clair Gantz, Gerald C. Whitnack, Clifford J. Holford, G. B. L. Smith, U. S. Naval Ordnance Test Station, China Lake, Calif. "Determination of Nitric Oxide and Nitrogen Dioxide in Admixture."

Thursday afternoon. M. L. Moss presiding.

C. F. Hiskey, Polytechnic Institute of Brooklyn, "Colorimetry Applied to High Absorbance Systems."

H. A. Liebhafsky, General Electric Co., "Some Unusual Cases in Photometric Analysis."

George Telep and D. F. Boltz, Wayne University, "Ultraviolet Spectrophotometric Determination of Molybdenum."

R. E. Kitson, E. I. du Pont de Nemours & Co., "The Simultaneous Determination of Cobalt, Copper, and Iron."

H. F. Beeghly, Jones and Laughlin Steel Corp., "The Behavior of Nitrogen and Some of Its Compounds in Steel"

P. E. Wenger, D. Monnier, Y. Rusani, University of Geneva, "The Use of Sensitive Reactions in Semi-Quantitative Determinations" (Translated and presented by Henry Freiser)

Thursday morning. J. J. McGovern presiding.

N. D. Coggeshall, Gulf Research and Development Corp., "Determination of Organic Functionality by Molecular Spectroscopy"

C. W. Young, M. R. Meeks, V. E. Whittier, Dow Chemical Co., "Some Considerations on the Determination of Low Molecular Weight Polar Solutes in Non-Polar Solvents"

John U. White, Perkin-Elmer Corp., "Applications of a Double Beam Infrared Spectrophotometer"

D. D. Friel, E. I. du Pont de Nemours & Co., "Analysis of Plant Samples with Infrared Gas Analyzers"

James D. Strouupe, Rohm and Haas Co., "Infrared Analysis of Certain C_3-C_4 Hydrocarbon Mixtures"

Thursday Afternoon. F. A. Miller presiding

J. S. Ard, Thomas D. Fontaine, U. S. Department of Agriculture, "Triethylamine Addition as a Means of Increasing the Applicability of Infrared-transmitting Solvents"

H. G. Monteith, Aluminum Research Laboratories, "Quantitative Infrared Analysis of Solid Isomeric Mixtures."

J. Seidman, Sinclair Refining Co., "Infrared Analysis of Cis- and Trans-Decalin"

R. A. Friedel, U. S. Bureau of Mines, "Infrared and Ultraviolet Spectra of Phenols"

Thursday morning. J. R. Churchill presiding.

M. F. Hasler, Applied Research Laboratories, "The Direct-Reading Analysis of Stainless and Tool Steels Covering Wide Ranges of Composition"

R. W. Callon, L. P. Charette, Aluminium Laboratories Limited, "Direct Reading Methods for Analysis of Aluminium and Aluminium Alloys Using Pin Samples"

George Wiener, Westinghouse Electric Corp., "The Effect of Heat Treatment and Composition on the Spectrographic Determination of Carbon in Steel"

Galen Porter, Union Carbide and Carbon Research Laboratories, "The Spectrochemical Determination of Magnesium in Cast Iron"

W. B. McCreary, International Harvester Co., "Factors Influencing the Spectrographic Analysis of Silicon in Gray Iron"

Thursday evening. G. W. Kelch presiding

Grant T. Wernimont, Eastman Kodak Company, "Design and Interpretation of Two-Factor Experiments

This session will be followed by an informal social hour.

Friday morning. R. A. Friedel presiding

Lionel S. Goldring, Roland C. Hawes, Arnold O. Beckman, Charles D. Coryell, Michael E. Stickney, National Technical Laboratories, "Anomalies in Extinction Coefficients at Low Absorbancies"

D. L. Timma, Mound Laboratory, "A Modified Beckman Spectrophotometer and its Performance"

J. R. Anderson, J. J. McGovern, Mellon Institute, "Spectrophotometric Detection and Determination of Thianaphthene in Naphthalene"

J. E. Newell, U. S. Rubber Co., "Residual Monomer in Polystyrene—A Spectrophotometric Method"

Alvin S. Glessner, Jr., A. C. Whitaker, N. D. Coggeshall, Gulf Research and Development Corp., "Ultraviolet Absorption Analysis for N, N'-di-sec-butyl p-phenylenediamine in Gasolines."

Frank P. Hazlett, Roy B. Hannan, Jr., Joseph H. Wells, Mellon Institute, "Determination of Anthracene in Crude Anthracene Cakes by Ultraviolet Spectrophotometry."

Friday morning. Mary E. Warga presiding

B. F. Scribner, National Bureau of Standards, "Standardization of Spectrographic Analytical Methods"

J. Sherman, Philadelphia Naval Shipyard, "Stability of Spectra as Determinable by Statistical Analysis of Experimental Data"

John Harley, George Peterson, George Welford, U. S. Atomic Energy Commission, "Spectrographic Determination of Beryllium in Air Dust Samples"

E. K. Jaycox, Bell Telephone Laboratories, "The Quantitative Spectrochemical Analysis of Ashes, Deposits, Liquids, and Other Miscellaneous Samples"

J. T. Rozsa, N. A. Grondin, J. Golland, National Spectrographic Laboratories, Inc., "Crucible Fusion Techniques of Spectrographic Semi-Quantitative Analysis"

Alfred T. Myers, U. S. Geological Survey, "An Improved Cutting Tool for Spectroscopic Electrodes"

B. F. Scribner, J. C. Ballinger, National Bureau of Standards, "Spectrochemical Analysis of Bronzes by the Porous Electrode Technique."

J. A. Norris, Massachusetts Institute of Technology, "Spectrographic Analysis of Beryllium Metal"

Friday afternoon. J. C. Redmond presiding

W. A. Kirklin, Hercules Powder Co., "Standardization in Analytical Chemistry"

Calvin Golumbic, Bureau of Mines, "The Separation and Analysis of Phenols by Countercurrent Distribution"

L. A. Wooten, W. G. Galdner, Bell Telephone Laboratories, Inc., "Low Pressure Techniques: The Determination of Oxygen and Carbon in Metals"

E. B. Read, L. P. Zopatti, Massachusetts Institute of Technology, "The Determination of Oxygen in Zirconium Metal"

L. C. Copeland, F. S. Griffith, The New Jersey Zinc Co., of Pa., "The Manual Polarograph for Rapid Routine Determinations—Lead and Cadmium in Zinc"

Willard P. Tyler, Earl C. Gregg, The B. F. Goodrich Research Center, "An Analytical Polarographic Study of the Bis (Dialkylthiocarbamyl) Disulfides and Dialkyldithiocarbamates"

Allen M. Goldstein, Tracerlab Incorporated, "Some Uses of Tracer Techniques in Analytical Chemistry"

Friday afternoon. J. H. Lieblich presiding.

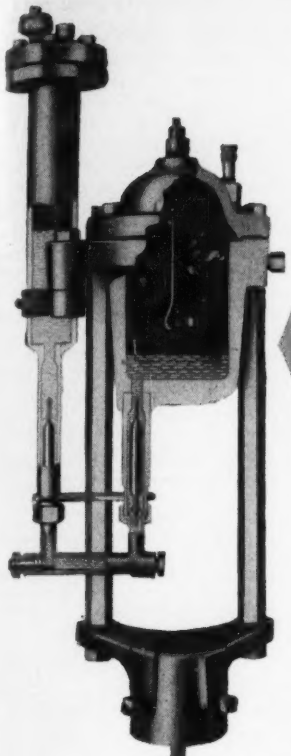
Harold P. Klug, Mellon Institute, "Recent Applications of X-Ray Diffraction in the Analytical Field"

William Priestly, Jr., Esso Laboratories, "Fluorescence Spectroscopy"

Anne L. Conrad, Winifred C. Johnson, Standard Oil Co. of Ohio, "Flame Photometer Techniques for Determining Typical Additives in Petroleum Oils"

Richard H. Hughes, Westinghouse Research Laboratories, "Microwave Spectroscopy and Chemical Analysis"

FINAL NOTICE
of Instrumentation Contest
See Page 94



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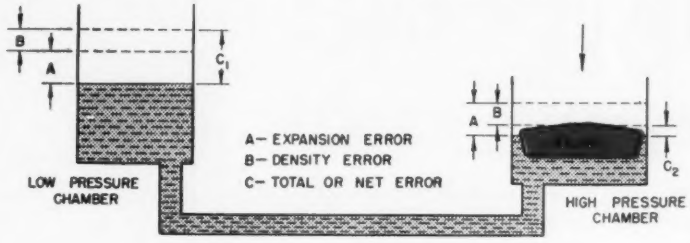

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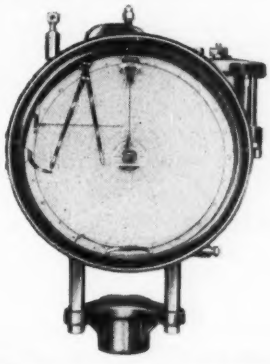

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Regulation of pH

Continued from page 38

requiring large pumps, there may be objections to this system especially if costs of circulating unused reagent are considered important. In such cases, it has not been uncommon practice to replace the overflow loop with a level controller, as illustrated in Fig. 83, which throttles the pumping load to exact process requirements.

The effective flow capacity of the control valve varies as the square root of hydrostatic head of reagent above, and variations in elevation of the head box affect the valve rating. There is no important limitation to maximum elevation of the head box except cost of piping and handling equipment and pumping or transportation costs. However, the higher the head tank, the smaller must be the control valve for a given concentration of reagent. As would be expected, however, increased elevation can be compensated for a fixed valve size, by decreased reagent concentration, or, conversely, decreasing elevation requires increased concentration in a square-root ratio.

A lower limit to elevation of head box is established by practical operating conditions. In many cases, the box has been placed at a one-foot or two-foot elevation to

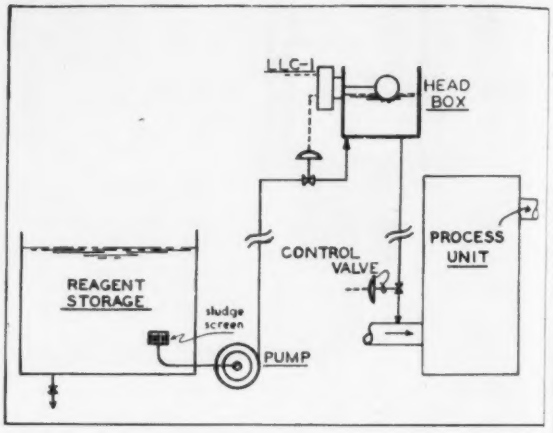

Fig. 83. Reagent supply system incorporating small-volume head box (5 to 10 gallons) and regulated delivery.

compensate for an otherwise oversized valve, and in some cases connected to the valve through a long connecting pipe. This has not been found by the writer to be good practice since, aside from the evils of an oversized valve, the box may be displaced horizontally from the valve, and friction of connecting piping limits pressure drop across the control valve to a small portion of the total at open-valve positions. It does not respond with positive action and lacks control characteristics normally inherent when it commands the major portion of pressure drop in the feed system.

Connecting piping should preferably be smooth-bore tubing and should be sized in accordance with standard piping tables to allow no less than 50 percent of the total pressure drop across the valve. A minimum size of half-inch is usually recommended for small flows and the valve body is limited to this minimum size. Commercial air-operated valves are adaptable to adjustment for smaller flows of some reagents by means of variable size trim in a standard half-inch body.

The minimum head may be a matter of choice with engineers depending on plant conditions and piping costs, although the writer has established, where possible, a minimum of 4.0 ft. and preferably 6.0 ft. for short connected installations. If the horizontal displacement is 20 ft. or more, an empirical minimum of 10 ft. hydrostatic head has been adopted. Volume of the head box may vary with applications, but average control installations require a head box no larger than 5 to 10 gallons capacity.

One might ask: "Why use a head box and why use a valve? A pump is necessary to distribute reagent, so why not use a controllable pump to feed reagent directly to the process from the reagent storage? Why pay for the

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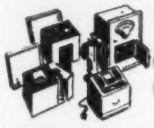

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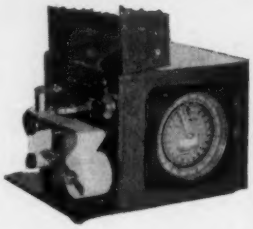

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installation of a head box?" This is a question which might be expected from any serious-minded engineer; it is a just question. Whether a head box or other feed device is used depends on cost requirements and plant limitations and pressure requirements of the feed device. A head box is limited to atmospheric pressure feed and is simple and fool-proof in operation but loses cost advantages when a large volume of reagent must be handled. It is recommended especially for plants having little modern facilities and untrained personnel for instrument maintenance and operation.

Direct feed of reagent by positive-displacement proportioning pumps is of particular importance when reagent must be injected into a pressure system. The writer has found a variable-stroke type quite satisfactory for injecting reagent into digesters and similar pressure vessels. Such pumps have also been used with success in water treatment and sewage disposal plants and have been especially well adapted to cascaded flow-pH installations

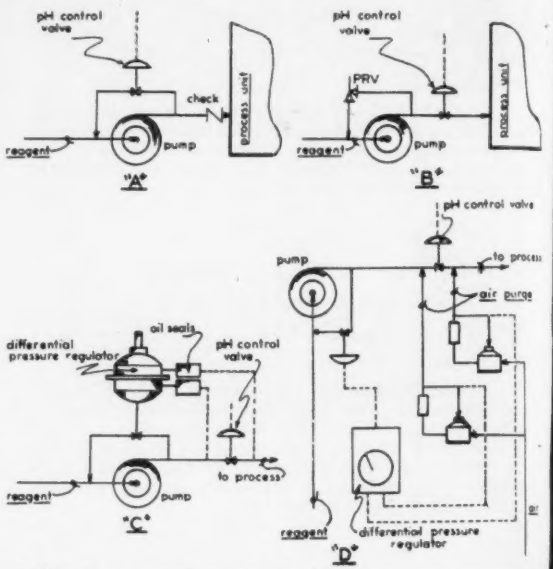

Fig. 84. Four accepted methods of maintaining constant pressure drop across pH control valve.

for controlling quiescent basins of high retention. They have the principal advantage that a head box and valve are not required and variations in supply pressure are without effect, if variations do not exceed a maximum or fall below a minimum limit. They are also especially well adapted to feeding small volumes of reagent.

The important advantage of smooth-acting control valves is their rapid response to fluctuating demands. They are generally preferred for direct high-rate neutralization reactions and processes having high buffer index and abrupt load swings. When properly applied, they effect an instantaneous transfer of reagent which is a *sine qua non* of good pH regulation. However, uniformity of flow characteristics (i. e. position *vs.* gpm. throughput) requires constant pressure drop across the valve at all positions; and, if gravity feed is not satisfactory or applicable, a number of methods may be, and have been, used successfully to maintain constant pressure drop as indicated in Fig. 84.

Fig. 84-A is a common method of applying the control valve as a by-pass around a constant-volume pump to regulate reagent feed. It is limited to positive pressure discharge and has the property of "reversing" effective valve characteristics. In other words, the effective flow of reagent to the process is a reciprocal characteristic of normally direct-connected valves. In some cases, this characteristic may be of importance to correct an otherwise effective narrow throttling range of a direct-connected valve.

Fig. 84-B has the advantage of wider turn-down and is applicable to both negative and positive pressure systems. Its principal weakness is the pressure relief valve which

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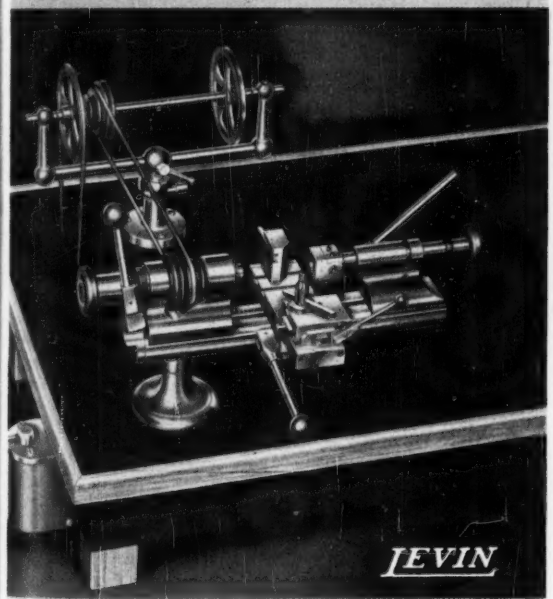

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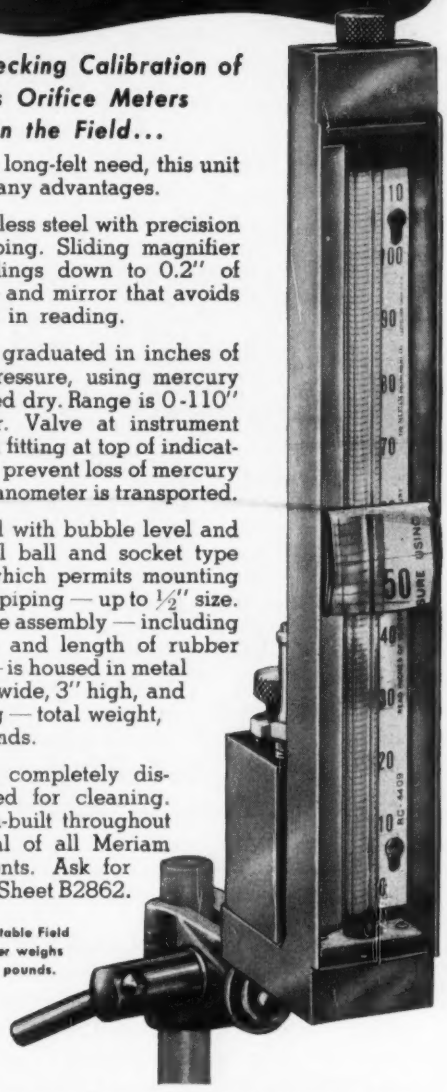

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must be simple in construction and unaffected by chemical action of the reagent.

The method illustrated in Fig. 84-C has been used satisfactorily on applications similar to pH and should present no serious difficulty in pH control. It consists of a pressure-loaded regulator connected across the control valve through seal pots containing an immiscible oil which also fills the regulator head. It regulates pump by-pass to maintain required pressure across the control valve.

An air purge system (Fig. 84-D) was recently applied successfully by the writer to a process in which the reagent was a heavy syrupy material. Air purge across the valve is controlled by two constant-differential pressure regulators which maintain constant pressure-drop across a fixed orifice, thus establishing fixed purge into the reagent line. Pressure differences between the two regulators is measured and recorded by a recording pressure-difference controller which operates a by-pass around the reagent supply pump to maintain fixed drop across the control valve.

Other reagent feed systems have been used and still others may be designed to operate in a specific manner to accomplish desired end results. Cost analysis and performance limitations are the guiding factors which determine the best method for a given job.

It is a customary procedure in water treatment and waste disposal practice to feed reagent into a long trough having one saw-toothed edge for equalized distribution of reagent across a Parshall flume or open channel; or sometimes the reagent valve may feed directly into a large weir box, which, in turn, gages reagent flow and spills it into the treating channel.

If reagent flow must be gaged, it should be done another way and the weir box eliminated entirely since it delays reagent transfer by virtue of its supply-side capacity lag. This condition applies in general to all distributors and transfer devices which may be connected to the discharge side of the reagent control valve. Their volume hold-up should be minimal, and line sizes should be *as small as possible*, to permit high velocity transfer of reagent to the process. Saw-toothed distribution boxes should not be of excessive width, since the added volume requires reagent and time to fill it and delays transfer to the process. If the distributor is long and spans a wide flume, it should be fed uniformly through a branched discharge header from the valve, and the header should be sized appropriately for maximum transfer velocity.

The same condition applies to "T" head distributors sometimes used in open-trough applications of industrial plants. It is not uncommon practice to terminate the valve discharge line into a submerged "T" distributor for control in open troughs, the downstream side being drilled with a multiplicity of holes to "fan" reagent into the flowing stream. Ordinarily, one may find the concept good but applied practice poor. An inspection of such distributors that have been in service usually reveals a "T" branch of larger size pipe than the feed line and, not uncommonly, the end holes plugged entirely or otherwise inactive, and the center section taking all reagent feed.

The important feature of design of "T" distributors is their velocity-distance component. Each branch should be sized by reference to Fig. 45 to give a velocity-distance component equal to twice the nominal velocity-distance component of the feed header which, conversely, should equal one-half the sum of both branches. For example, if the feed header transfers one gallon of reagent a distance of one foot in one second, each branch of the "T" distributor should be appropriately sized to transfer this same gallon of reagent a distance of two feet in one second. Sizing of the discharge holes is also important and should follow a pattern of increasing diameter toward the ends of the branch to provide decreasing pressure drop.

* * *

The technique of controlling pressure drop across the control valve has been widely applied to industrial control and offers advantages in pH regulation. For example a pH regulator may be cascaded with a liquid level or flow regulator as indicated in Fig. 85 in such a manner as to control pressure drop across the main control valve VA-1 by manipulating valve VA-2. The principal advantage of

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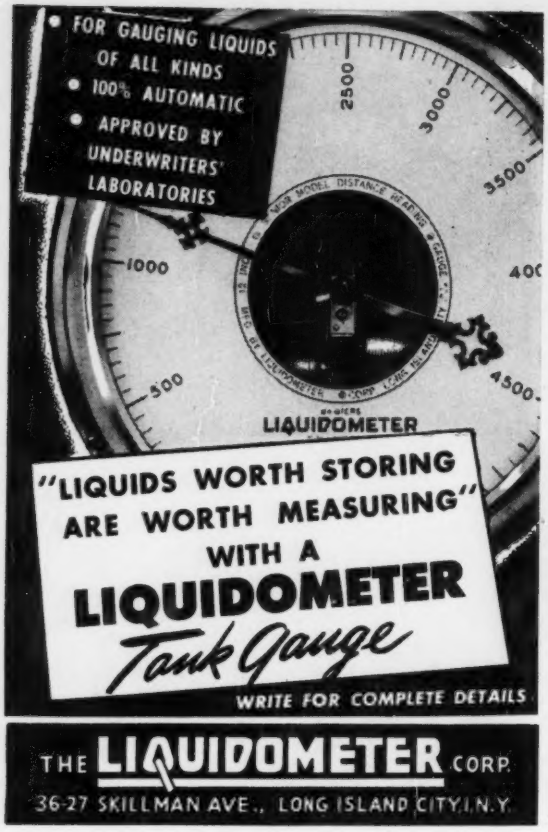
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this system is its inherent fail-safe characteristics but, like any other cascaded system, it must be appraised for its specific application.

Another novel application of the pressure-drop technique is illustrated in Fig. 86. A common influent stream is divided between two batteries of converters, one battery of which generates an alkaline material while output

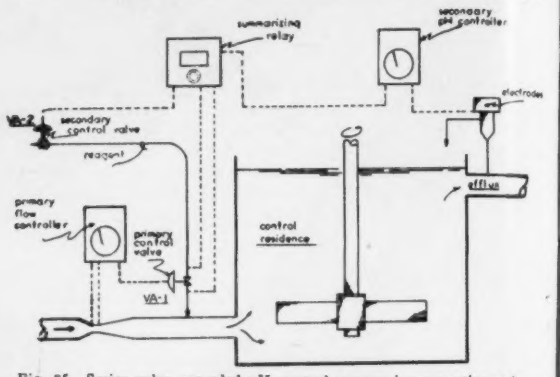

Fig. 85. Series valve cascaded pH control process incorporating primary reagent feed as a function of process liquor flow and secondary correction as a function of pH.

of the other battery is acidic. Effluents from these converters must be regulated in volume throughput to meet demands of subesequent process units, and must also be ratioed to adjust final pH.

Valves VA-1 and VA-2 adjust pH while VA-3 and VA-4 regulate throughput. The pH of the combined effluent streams is measured by recorder-controller pHC-1, which actuates simultaneously direct-acting valve VA-1 and reverse-acting valve VA-2. Level in the accumulator is a

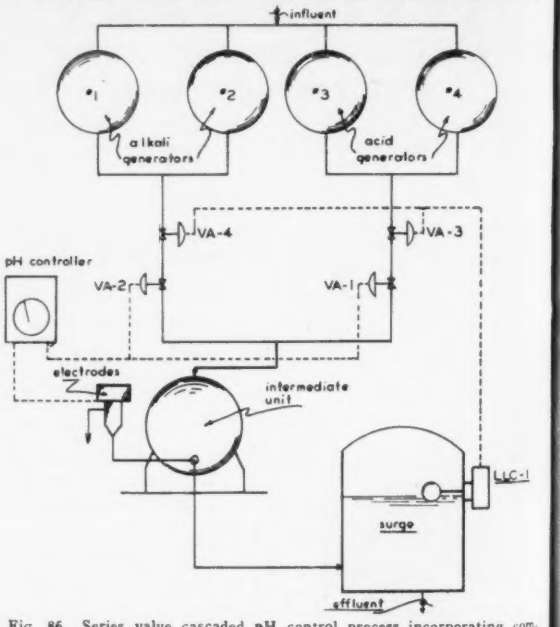

Fig. 86. Series valve cascaded pH control process incorporating combined throughput control and pH regulation. Unit regulators of this process are interdependent.

measure of throughput and LLC-1 becomes the flow regulator which actuates opposed-acting valves VA-3 and VA-4.

Although this process has unique features, it is basically unstable and requires external stabilization such as the intermediate capacity and accumulator to avoid individual regulators "fighting" one another. Should either battery of converters become clogged or "spent," either the flow regulator or pH regulator, or both will act to alleviate the condition. However, there is nothing to prevent under-

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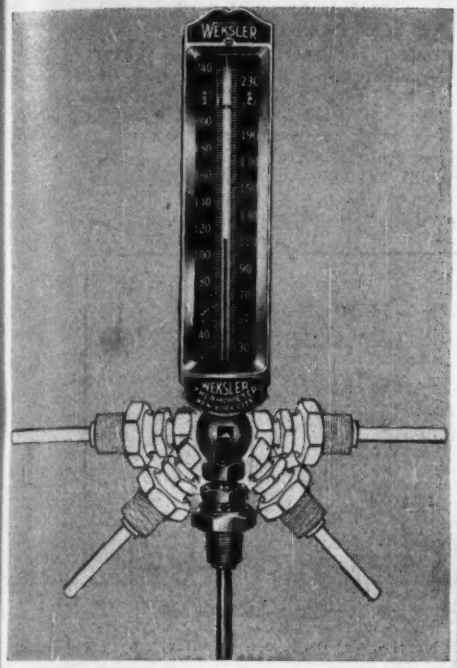
Swings A New Angle on Thermometer Installation



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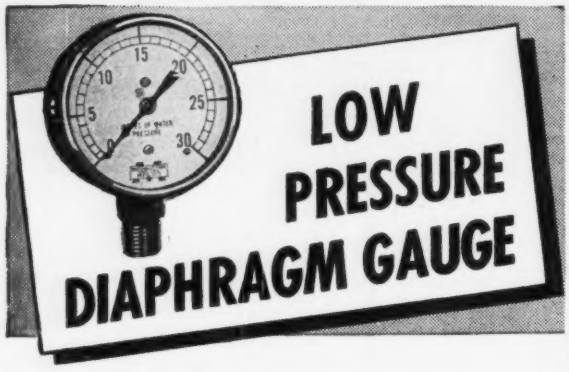

MARSHALLTOWN Figure 83 is a very sensitive instrument utilizing a diaphragm for pressure communication, and is recommended for extremely low pressure service.

The following standard dials reading in inches of water are available—0-15" 0-30" 0-60" 0-100" 0-150".

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It is available in the 2½", 3½", and 4½" dial sizes and mounted in a black enameled, deep steel case. Write for details and price.

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correction in the event of "spent" converters, except full closure of one valve and opening of the other. When this condition occurs, a closing contact sounds an alarm.

* * *

Needless to say that composition of reagent must be uniform for all applications to eliminate unnecessary loads on the regulator. If the reagent is a slurry of solid material suspended in a liquid vehicle, it is necessary to circulate it in a closed loop at sufficient velocity to prevent settling as described in the foregoing text. Butterfly valves have been used satisfactorily as vertical take-off controls on slurries of lime up to 16 percent (Fig. 87). Vertical up-take through the butterfly valve minimizes plugging of the wing at partial open positions.

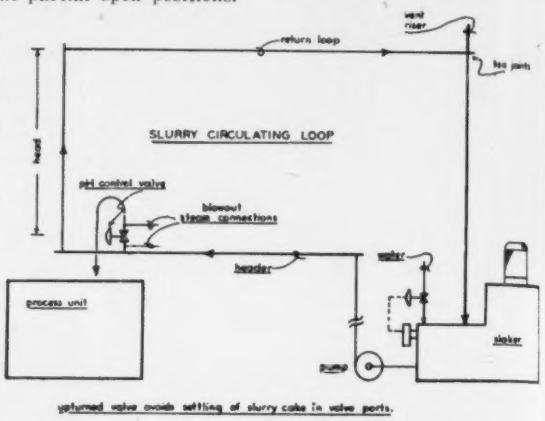


Fig. 87. Reagent slurries must be circulated constantly and agitated thoroughly to maintain uniform concentration and avoid plugging.

It has been found good practice to use flanged tees at all pipe turns and install steam purge lines on both sides of the valve to facilitate removal of cake or plugs which may accumulate during shut-down. Furthermore, the supply header and return loop should slope toward the supply source to permit self-drainage of the line in event of pump stoppage. Head on the valve is established by a vertical riser in the loop. Siphoning action of the return leg is broken by means of a vent riser at the point of down-take.

In many cases it is customary practice to feed dry chemical reagent to a process with a mechanical feeder. When such equipments are used as part of the pH control loop wherein a pH regulator adjusts feed rate directly, it is desirable to avoid as much transfer lag and supply-side storage lag as possible. In general it will not be convenient to reduce these lags to values comparable with liquid feed installations; therefore all precautions should be taken to make reagent transfer to the process as direct as possible, but with due regard for *equilibrium lag* which may result if sufficient time is not allowed for dissolving and occlusion reactions to reach equilibrium.

To be continued

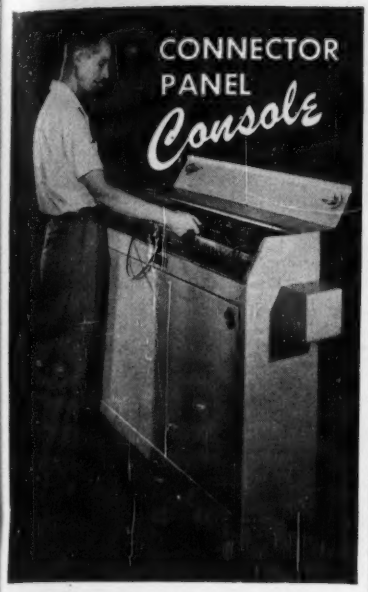
FINAL REMINDER

Dead-line for the $500 Instrumentation Essay Contest is Tuesday, January 31st.

Entries must be mailed early enough to be received not later than that date at the office of the sponsor, The Instruments Publishing Company.

Address entries to Contest Editor, 921 Ridge Avenue, Pittsburgh 12, Pa.

For rules, see page 934 of October issue; or page 1009 of November issue; or page 1124 of December issue.



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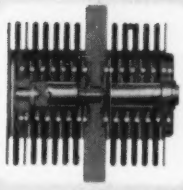

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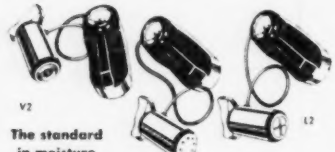

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Manufacturers New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 99.

S-1 LABORATORY APPARATUS. Two bulletins, "Laboratory Spotlight No. 4" and "Laboratory Spotlight No. 5" illustrate and describe maker's laboratory instruments and apparatus. No. 4 covers spectrophotometer, precision balance, x-ray diffraction unit, washers, stirrers, etc.; No. 5 covers "Polaro-analyzer," torsion balance, thermometers, hot plates, etc.; No. 5 contains 1947 revised atomic weight table.—Harshaw Scientific Div., Harshaw Chemical Co., Cleveland 6, Ohio.

S-2 FLOW CONTROL VALVE. 4-page Bulletin WH-100 illustrates and describes maker's flanged silent check valve; lists exclusive features; shows typical applications.—The Williams Gauge Co., 1620-22-24 Pennsylvania Ave., Pittsburgh 12, Pa.

S-3 "GENERAL RADIO EXPERIMENTER." 8-page Vol. XXIV, No. 6 issue of this house organ features articles on maker's "Type 1022-A" F-M standard-signal generator, and "Type 1023-A" amplitude modulator—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-4 DRAFTING TEMPLATES. 2-page circular illustrates use of maker's "Flowplanner" template for flow plan drawing; contains sample drawings, full-size illustrations of templates.—Timely Products Co., Box 206-B, Columbus 9, Ohio.

S-5 VACUUM COATING UNITS. 16-page bulletin illustrates and describes maker's units for coating metal and other objects in high vacuum; discusses process and various units; lists advantages, characteristics.—Distillation Products, Inc., Rochester 13, N. Y.

S-6 AIR-OPERATED CONTROLLERS. 32-page Bulletin No. A120 illustrates and describes maker's new line of "Series 500" air-operated controllers; lists features, complete data on on-off, proportional, reset, derivative, reset plus derivative models.—The Bristol Co., Waterbury 20, Conn.

S-7 STEAM, AIR, OIL, ETC. STRAINERS. 4-page Bulletin S-202 describes and illustrates maker's fine screen strainers for hot or cold services in steam, water, air, oil and gas lines; lists types, sizes; discusses uses—Yarnall-Waring Co., Chestnut Hill, Philadelphia 18, Pa.

S-8 FLUE GAS ANALYZER. 4-page Bulletin No. 1136B illustrates and describes maker's continuous indicating and recording flue gas analyzer; discusses theory of operation, construction features; lists available units, accessories.—Instruments Div., Davis Emergency Equipment Co., Inc., 47 Halleck St., Newark 4, N. J.

S-9 AUTOGRAPHIC TITROMETER. 12-page Bulletin 640A describes and illustrates maker's "Recordomatic" titrometer for automatic control of reagent feeding; discusses advantages, operation, range; contains "Question and Answer" page; gives ordering data.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

S-10 ILLUMINATED LAYOUT PLATE WITH MICROSCOPE. 2-page bulletin describes and illustrates maker's illuminated layout plate with microscope for surface inspection; lists features, specifications.—All American Tool & Mfg. Co., 1014 Fullerton Ave., Chicago 14, Ill.

S-11 MICROPHOTOMETER. 4-page bulletin describes and pictures maker's "Romicron" microphotometer; lists special features; discusses calibration procedure.—Paul Rosenthal, 505 Fifth Ave., New York 17, N. Y.

S-12 RADIATION COUNTER. 4-page bulletin illustrates and describes maker's model "RM 1" portable, battery-operated radiation counter; discusses typical applications; specifications.—The Nucleonic Corp. of America, 497 Union St., Brooklyn 31, N. Y.

S-13 FLOW-RATE INDICATOR. 2-page bulletin describes and pictures maker's "Floguide" gas flow-rate indicator; lists features; gives capacity and dimension tables.—Fisher & Porter Co., Hatboro, Pa.

S-14 TIMING DEVICES. 6-page bulletin describes and illustrates maker's timing devices, switches, etc.; lists applications, features, data on each.—M. H. Rhodes, Inc., 30 Bartholomew Ave., Hartford 6, Conn.

S-15 "hp JOURNAL." 4-page Vol. 1, No. 3 issue of this house organ features part one of a two-part article titled "Design Notes on the Resistance-Capacity Oscillator Circuit."—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-16 "CEC RECORDINGS." 10-page Vol. 3, No. 4 issue of this house organ features article titled "Magnetic Susceptibilities of Heavy Metal Compounds"; also articles on maker's "Titrilog," oscillograph record magazine, mass spectrometer.—Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif.

S-17 "INSTRUMENT NEWS." 8-page Vol. 1, No. 1 issue of this house organ features an article titled "Use of Infrared Expands in Drug, Biochemical Fields"; contains section "Tricks of the Trade" on use of electro-optical instruments.—The Perkin-Elmer Corp., Glenbrook, Conn.

S-18 ELECTRONIC CONTROL. 64-page book, "Cutting Production Costs with Electronic Controls," illustrates and discusses 45 case studies on industrial control problems solved through use of electronics.—Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.

S-19 LABORATORY ROD CLAMPS. 2-page bulletin illustrates and describes maker's rod clamps for semi-permanent setups in the laboratory; lists features, types, dimensions.—Chandler & Stedman, 398 Newton St., Waltham 54, Mass.

S-20 "SCIENTIFIC APPARATUS AND METHODS." 38-page fall 1949 edition of this house organ features article titled "The Polarography of Carbonyl Compounds"; Section two lists new, reinstated, discontinued items, specification changes; encloses "Table of Half-Wave Potentials."—E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.

S-21 COMBUSTION CONTROLLERS. 12-page Bulletin SC-2.1 describes and illustrates maker's combustion controllers; discusses uses, operation, design and construction, capacities and pressures, selection procedure; gives typical applications; lists features.—Selas Corp. of America, Philadelphia 34, Pa.

S-22 STANDARD MEASURING MACHINE. 8-page Circular No. 523 illustrates and describes maker's standard measuring machine; discusses operation, features, accessories; lists specifications.—Pratt & Whitney, West Hartford 1, Conn.

S-23 STRAIN GAGES. 12-page Bulletin No. 279-A describes and illustrates use of maker's "SR-4" bonded resistance wire strain gages in stress analysis; illustrates eight circuits with accompanying instruments.—Baldwin Locomotive Works, Philadelphia 42, Pa.

S-24 MEGOHMMETER. 4-page Bulletin No. 1029 illustrates and describes maker's "Model 29" megohmmeter for resistance measurement over a range from 300,000 ohms to 20,000,000

megohms; discusses principle of operation, accuracy; lists specifications.—Herman H. Sticht Co., Inc., 27 Park Place, New York, N. Y.

S-25 GAS AND LIQUID ANALYZER. 4-page Bulletin No. DZ-4 describes and illustrates maker's "Lira" infrared gas and liquid analyzer; discusses operation, applications.—Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh 8, Pa.

S-26 "THE LABORATORY." 48-page Vol. 19, No. 2 issue of this house organ features article titled "Taste Takes a Trip to the Laboratory"; containes articles on maker's electroviscometer, temperature and pressure recorders, etc.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

S-27 A-C REGULATORS. 12-page Catalog No. A-1049 illustrates and describes maker's a-c electronic voltage regulators; contains performance chart; lists electrical and mechanical specifications, and unusual voltage conditions of each model.—Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

S-28 D-C POWER SOURCES AND SUPPLYS. 8-page Catalog No. B-1049 describes and illustrates maker's "Nobatron" d-c. power sources and power supplys; lists electrical and mechanical specifications.—Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

S-29 CARBIDE GAGES. 8-page bulletin lists ranges, accuracies, prices of maker's go, not go, and progressive standard plug and ring gages with carbide inserts.—Arthur A. Crafts Co., Inc., 603 Newbury St., Boston 15, Mass.

S-30 MACHINE SHOP GAGES AND TOOLS. 8-page bulletin illustrates and describes maker's diamond and carbide tools, wear parts, gages, diamond dust; lists prices.—Arthur A. Crafts Co., Inc., 603 Newbury St., Boston 15, Mass.

S-31 "S-L INSTRUMENT NOTES." 4-page No. 12 issue of this house organ features article titled "The Meaning of 'Natural Frequency'"; also contains index of articles published in preceding issues.—Statham Laboratories, 9328 Santa Monica Blvd., Beverly Hills, Calif.

S-32 CONTROL VALVES. 2-page folder describes and illustrates maker's control valves for industrial use; lists sizes, uses of temperature regulators, feed regulators, etc.—Atlas Valve Co., 280-284 South St., Newark 5, N. J.

S-33 "SK ENGINEERING NEWS." 4-page Vol. 1, No. 3 issue of this house organ contains article titled "Rotameters Can Provide Close Control Over Batch Process"; also features items on maker's rotameters, condensers, fume scrubbers, oil heaters.—Schutte & Koerting Co., 1185 Thompson St., Philadelphia 22, Pa.

S-34 PRECISION ANEMOMETER. 2-page bulletin illustrates and describes maker's "Precision Air-Meter" for measuring low air or gas velocities; lists characteristics, advantages; discusses principle of operation.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

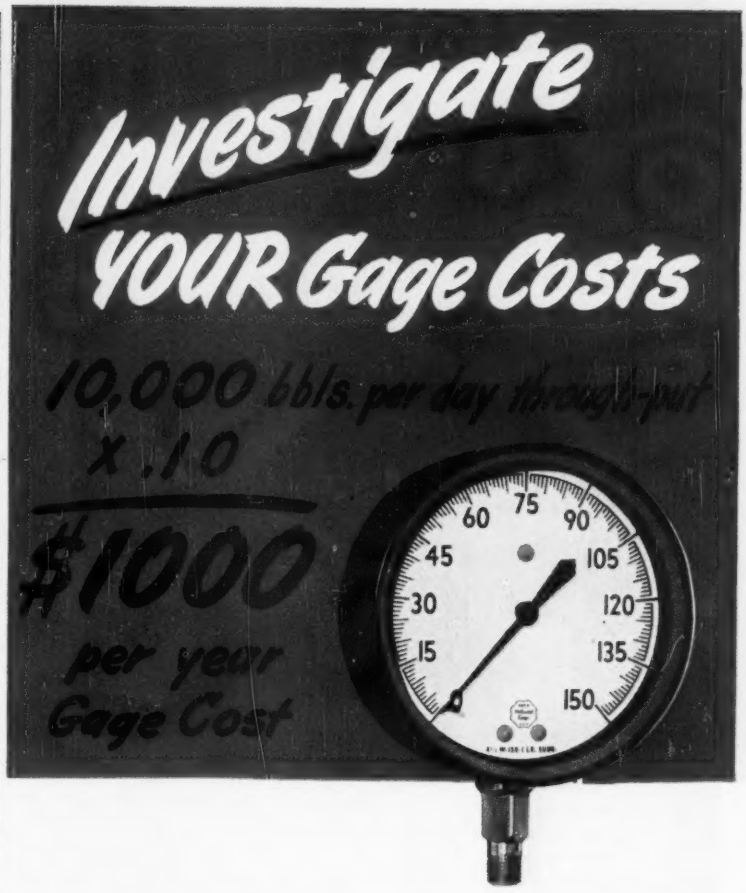
S-35 SHIP POSITION PLOTTING. 4-page reprint from The Oil and Gas Journal, July 7, 1949, of article titled "A Method of Surveying by Use of Radio Waves" and 2-page bulletin, "Raydist Automatically Records A Vessel's Exact Position and Course," discuss history, development and operation of maker's "Radist" ship position and course plotting system.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

S-36 ELECTRONIC STANDARD CELL. 2-page bulletin describes and illustrates maker's electronic standard cell; lists features, characteristics.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

S-37 PORTABLE ANEMOMETER. 2-page bulletin illustrates and describes maker's "Air-Meter" portable anemometer; lists features, characteristics; discusses principle of operation; lists accessories.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

S-38 "THE OHMITE NEWS." 2-page November issue of this house organ features article titled "More Uniform Control Achieved with Taper-wound Rheostats"; also contains articles on maker's resistors.—Ohmite Manufacturing Co., 4835-41 Flournoy St., Chicago 44, Ill.

S-39 COLOR MEASUREMENT. 4-page bulletin illustrates and describes maker's "Color-



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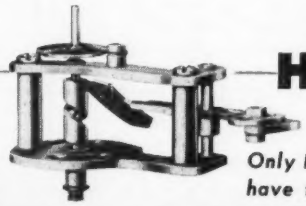

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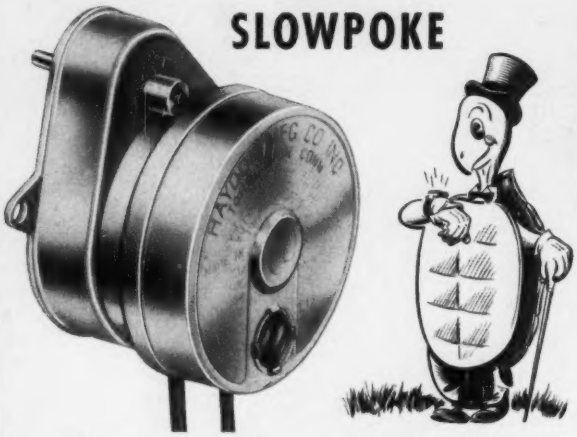

Designers and manufacturers concerned with the excessive space requirements and high cost of external reduction gearing will welcome this new slow speed timing motor. The series 4400 requires minimum space and provides, at comparatively low costs, speeds from 6 hours to 7 days per revolution. The careful design, expert engineering and precision manufacture, are advantages common to all Haydon motors.

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Eye," a new industrial color measuring and comparison instrument designed to replace the human observer in precise color-matching problems; lists features and technical specifications.—Instrument Development Laboratories, Inc., 163 Highland Ave., Needham Heights 94, Mass.

S-40 THICKNESS MEASUREMENT. 2-page bulletin describes and illustrates maker's "IDL Opti-Mike" thickness microscope which permits, for the first time, precise thickness measurement of glass, plastics, quartz, and any other transparent material where physical access to one side only is possible; lists performance characteristics, typical applications.—Instrument Development Labs., Inc., 163 Highland Ave., Needham Heights 94, Mass.

S-41 WASTE CONTROL. 16-page booklet, "Solving Industrial Crimes—Case No. 38," describes solution to one company's excess lighting load problem; lists applications of maker's recording instruments in various industries to help eliminate waste.—The Esterline-Angus Co., Inc., Indianapolis 6, Ind.

S-42 ELECTRICAL INSTRUMENTS. 4-page Bulletin C-50 illustrates and describes maker's switchboard instruments; lists specifications, types available; encloses 8-page price list.—Reliance Instrument Co., 3027 W. Van Buren St., Chicago 12, Ill.

S-43 MACHINABILITY TESTER. 8-page bulletin illustrates and describes maker's "MSE Schlesinger" machinability tester for measuring machinability in establishing machinability standards; discusses operation, application; explains "machinability index" and tool standardization.—Vanton Equipment Corp., Empire State Bldg., New York 1, N. Y.

S-44 TIMING MOTORS. 4-page bulletin describes and illustrates maker's "SC" and "LC" timing motors; lists special features, specifications, dimensions, speeds.—International Register Co., 2616 W. Washington Blvd., Chicago 12, Ill.

S-45 VARIABLE-AREA RECORDER AND REPRODUCER. 4-page bulletin illustrates and describes maker's variable-area recording and reproducing instruments for analysis of seismic impulses under laboratory conditions; lists specifications; describes power supply.—Seismograph Service Corp., Tulsa, Okla.

S-46 VIBRATION TEST MACHINES. 4-page bulletin describes and illustrates maker's "Type RVCG" constant G, and "Type RVCA" constant-amplitude vibration test machines; lists features, dimensions, specifications.—L.A.B. Corp., 31 Union Pl., Summit, N. J.

S-47 SHUTOFF VALVE. 2-page Bulletin No. 218 illustrates and describes maker's "21 Series" safety shut-off valve; lists features, applications.—The North American Mfg. Co., Cleveland 5, Ohio.

S-48 SIGNAL CALIBRATOR. 2-page bulletin describes and illustrates maker's "Electro-Cal" signal calibrator for laboratory measurements; lists special features, range, output specifications.—Industrial Electronics, Inc., 2457 Woodward Ave., Detroit 1, Mich.

S-49 INDUSTRIAL ANALYZER. 2-page bulletin describes and illustrates maker's "Model 247" portable electrical industrial analyzer; discusses operation, application; lists specifications.—Instrument Laboratories, 315 W. Walton Pl., Chicago 10, Ill.

S-50 "MODERN PRECISION." 8-page Vol. 9, No. 3 issue of this house organ features articles on maker's electrodes for industrial pH measurement, integrated control for furnaces, "Micromax" controllers and recorders in metals, process industries, ceramics, power, research, teaching and testing.—Leeds & Northrup Co., 4902 Stenton Ave., Philadelphia 44, Pa.

S-51 INDUSTRIAL MIRRORS. 16-page booklet, "A New Chapter in Reflectivity," gives brief history of development of maker's industrial reflecting surfaces; lists advantages, applications.—Pancro Mirrors, Inc., Glendale, Calif.

S-52 CONSTANT TEMPERATURE & HUMIDITY CABINET. 2-page bulletin illustrates and describes maker's "Model 206CD" constant temperature and humidity laboratory cabinet; lists features; discusses construction.—Food Technology Inc., 5903 Northwest Highway, Chicago 31, Ill.

S-53 LEVEL MEASUREMENT. 24-page Catalog 75 illustrates and describes maker's

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"Levelimeter" instruments for indicating, measuring and controlling liquid level and interface level; discusses features, applications.—Fischer & Porter Co., Hatboro, Pa.

S-54 TEMPERATURE INDICATORS. 8-page Bulletin GEC-565 illustrates and describes maker's thermocouple and resistance thermometers and accessories; gives specifications, classification tables, features.—Apparatus Dep't, General Electric Co., Schenectady 5, N. Y.

S-55 "WHAT'S NEW FOR THE LABORATORY?" 12-page No. 9 issue of this house organ contains articles on maker's laboratory apparatus, instruments, chemicals, glassware, etc.—Scientific Glass Apparatus Co., Inc., 49 Ackerman St., Bloomfield, N. J.

S-56 JACKS, PLUGS, SWITCHES. 12-page Catalog No. S49 describes and illustrates maker's phone jacks, plugs, switches; discusses several models of each; gives specifications, drawings. —Switchcraft, Inc., 1328-30 N. Halsted St., Chicago 22, Ill.

S-57 "hp JOURNAL." 4-page Vol. 1, No. 4 issue of this house organ features part two (conclusion) of article titled "Design Notes on the Resistance-Capacity Oscillator Circuit," contains typical characteristics chart of resistance-capacitance oscillators.—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-58 "GENERAL RADIO EXPERIMENTER." 8-page Vol. XXIV, No. 7 issue of this house organ features articles titled "A Precision Attenuator Having a Wide Frequency Range," and "An Acoustic Calibrator for the Sound-level Meter."—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-59 "CURRENTLY." 8-page Vol. 3, No. 2 issue of this house organ features article titled "Load Regulation" discussing use of voltage regulators, linear and non-linear loads.—Sorensen and Co., Inc., 375 Fairfield Ave., Stamford, Conn.

S-60 TRANSFORMERS. 18-page Catalog 1950-I describes and illustrates maker's output, input, interstage, plate and filament, power smoothing and swinging chokes, modulation and replacement type transformers; lists characteristics.—Peerless Electrical Products Div., Altec Lansing Corp., 161 Sixth Ave., New York 13, N. Y.

S-61 "WHEELCO COMMENTS." 4-page Vol. 9, No. 1 issue of this house organ features

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article titled "Interlocked Control System at Lima Register Company," and discusses maker's mobile temperature recorder and plastic extruders; encloses 2-page bulletin on maker's "Model 1300 Flame-trol."—Wheelco Instruments Co., Harrison & Peoria Sts., Chicago 7, Ill.

S-62 "HOW TO RUN A LATHE." 128-page Vol. 1, Edition 49 of this book contains nine chapters discussing fundamentals of operation of modern screw-cutting engine lathe.—South Bend Lathe Works, South Bend 22, Ind.

S-63 "CENCO NEWS CHATS." 28-page No. 66, Winter 1949-1950 issue of this house organ contains articles titled "American Petroleum Institute," "A Discussion of Laboratory Gas Burners," "Dairy Microscopes," "Automatic Vacuum and Pressure Control," and "The Laboratory Assistant" section on new ideas for better work.—Central Scientific Company, 1700 Irving Park Rd., Chicago 13, Ill.

S-64 AUTOMATIC PRESSURE, TEMPERATURE COMPENSATION. 4-page Bulletin M-51 describes and illustrates how maker's "Ring Balance" meters provide automatic compensation for pressure, temperature, or both.—Hagan Corp., Hagan Bldg., Pittsburgh 30, Pa.

S-65 TRANSFORMERS. 6-page loose-leaf reprint of Bulletin 149 for insertion in maker's binder illustrates and describes use of maker's linear variable differential transformers with Brown "Electronik" recorders.—Schaevitz Engrg., Crescent Blvd. at Drexel Ave., Pennsauken Twp., Camden 11, N. J.

S-66 "THE C-D CAPACITOR." 16-page Vol. 14, No. 12 issue of this house organ features article titled "High-sensitivity AF-RF Signal Tracer"; contains regular "The Radio Trading Post" section for "buyers, sellers and swappers."—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

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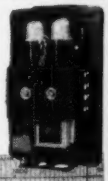

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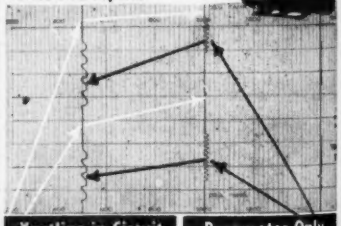

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